

MORPHOLOGY OF SOLO MAN

FRANZ WEIDENREICH

INTRODUCTION

G. H. R. VON KOENIGSWALD

VOLUME 43 : PART 3
ANTHROPOLOGICAL PAPERS OF
THE AMERICAN MUSEUM OF NATURAL HISTORY
NEW YORK : 1951

MORPHOLOGY OF SOLO MAN

MORPHOLOGY OF SOLO MAN

FRANZ WEIDENREICH

INTRODUCTION

G. H. R. VON KOENIGSWALD

VOLUME 43 : PART 3
ANTHROPOLOGICAL PAPERS OF
THE AMERICAN MUSEUM OF NATURAL HISTORY
NEW YORK : 1951

FOREWORD

STUDENTS OF HUMAN EVOLUTION have long awaited the publication of a complete and authoritative description of the Solo skulls, the first of which were discovered nearly 20 years ago. The additional hominid fossils from Java that have come to light since then have, if anything, enhanced the significance of the Solo remains and increased the need for the information that these documents can provide. The reasons for the delay in presenting such a report are set forth by Dr. G. H. R. von Koenigswald in his following narrative of the fortune of these precious fragments of early man, and I need not go into them here.

The task of describing the morphology of the Solo remains was intrusted to Dr. Franz Weidenreich whose eminence and experience in this field made him a natural choice, and all of us, I am sure, felt that the report which we anticipated from him would stand not only as definitive of Solo man but as a model of anatomical exposition. It is, therefore, all the more regrettable that the magnum opus begun by Weidenreich on a Michelangesque scale, rich in significant detail and masterly in conception, should now lie before us in an incomplete state.

During most of the year 1947 and the spring of 1948, Weidenreich was deeply occupied at first with the preparation and casting of the fossil remains of Solo man, and later with their painstaking study. He began to commit his observations to paper some time during the winter of 1947, for I recall his expression of satisfaction about that time that he had finally reached this stage in his work. Later in the following spring he spoke to me of his relief at having finished the arduous business of recording his anatomical analysis, and I received the impression then that he had completed the major portion of his work. I knew that he was desperately eager to finish his monograph, for at his age time presses uncomfortably close and he still had one or two deferred projects he wanted to complete.

After his death in July, 1948, it fell to me, at Mrs. Weidenreich's request, to examine and to dispose of his scientific manuscripts. Among them I found the present paper on Solo man. Since Weidenreich, with the agreement of Dr. von Koenigswald, had previously arranged to

publish the results of his researches on Solo man in the Anthropological Papers of this museum, it now seemed possible and appropriate to proceed with that purpose. The prepared material on Solo man consisted of a manuscript in Weidenreich's own hand, a typescript which he had read in part and corrected or amended in his own hand, together with a number of plates, figures, and tables. In addition there were a few notes on the Solo tibiae. The text itself on examination proved to be incomplete, both the typescript and manuscript ending at the same point in the middle of a sentence and obviously in the course of a descriptive passage dealing with the cerebral surface of the base of the skull. The table of contents was carried no farther than this unfinished section. We have, therefore, no statement of the coverage which Weidenreich intended to give his subject, except in the illustrations which he had had prepared but had not specifically mentioned in his text and in the assemblage of tables. It is clear that he had much more in mind than he had time to set down, for the present text is largely concerned with a descriptive and analytical exposition of the morphology of the Solo skull as a whole and by individual bones. The corresponding section of his great work on the skull of *Sinanthropus* occupies only about a third of the total text. It can only be regarded as a major tragedy that he was unable to set forth the full account of his conclusions relating to Solo man.

The decision of how to deal with this incomplete text offered several problems. In view of the obvious importance of the Solo material, there could be no question of not publishing the manuscript, even though unfinished. On the other hand, any attempt by another hand to furnish the missing sections seemed unwise, since there were no notes to guide such a project in the form that Weidenreich might have approved. Moreover such an effort to complete the manuscript would have meant another delay. It was, therefore, finally decided to publish the available manuscript as it was found, since it formed an almost complete unit of the total design. We have then an admirable description of the Solo skull together with a study of the individual bones of the cranium and an ap-

praisal of the variation that exists in the total series. Although I hope that at a later date we may publish a section devoted to a fuller comparative study and the conclusions to be drawn from it, I think that Weidenreich makes clear enough in this section his conclusions on the phylogenetic relationships of Solo man.

The editorial policy I adopted in the preparation of the manuscript was one of minimal interference with the text. Weidenreich wrote English with considerable ease, but his mother tongue naturally affected the construction of his English sentences to some degree, and Teu-

tonic expressions occasionally appeared translated literally. Changes, however, were made with great restraint and only where repetition was obvious or where I felt that awkwardness of expression might obscure the intended meaning. But in no case were emendations made without a careful reëxamination of the casts and photographs of the original specimens. In several instances I have preferred to let an obscure passage stand than to run the risk of changing an emphasis or of substituting my interpretation for Weidenreich's.

HARRY L. SHAPIRO

CONTENTS

FOREWORD. HARRY L. SHAPIRO	205
INTRODUCTION. G. H. R. VON KOENIGSWALD	211
History of the Discovery	214
Geology and Paleontology	219
MORPHOLOGY OF SOLO MAN. FRANZ WEIDENREICH	222
Eugène Dubois and Solo Man	222
The Material as Described by W. F. F. Oppenoorth and Others	224
Nomenclature	226
The Material	227
Skull I	228
Skull II	229
Skull III	231
Skull IV	231
Skull V	231
Skull VI	232
Skull VII	233
Skull VIII	233
Skull IX	233
Skull X	233
Skull XI	235
Tibia A	235
Tibia B	236
Sex and Individual Age	236
Injuries	238
Morphological Character of <i>Homo soloensis</i>	239
The Skull	239
General Aspect	239
Norma Lateralis	240
Norma Frontalis	242
Norma Occipitalis	244
Norma Verticalis	245
Norma Basilaris	246
The Separate Cranial Bones	249
Frontal Bones	249
Parietal Bone	253
Endocast Relief of Frontal and Parietal Bones	254
Occipital Bone	255
Temporal Bone	269
Squamous Portion	269
Tympanic Plate	274
Petrus Portion	277
Mastoid Portion	279
Sphenoid Bone	280
Ethmoidal Bone	282
The Cerebral Surface of the Base of the Skull	282
LITERATURE CITED	287
EXPLANATION OF PLATES	289

TABLES

1. List of the Human Remains from Ngandong	217
2. The Mammalian Fauna of Ngandong (Revised)	219
3. General Peculiarities of the Solo Skulls Bearing on Sex and Age	237
4. Curvature Height Indices of the Frontal Squama of Solo Skulls Arranged According to the Range of the Index (in Millimeters)	250
5. Thickness of the Torus Supraorbitalis Proper of Solo Man, Measured at Its Free Anterior Margin (in Millimeters)	251
6. Length-Breadth Measurements (Chord l-o in Proportion to Chord ast-ast) of the Occipital Squama of Solo Man and <i>Pithecanthropus robustus</i> (in Millimeters)	256
7. Length of the Mid-sagittal Chords of the Upper and Lower Scales (l-i and i-o) of the Occipital Squama of Solo Man and <i>Pithecanthropus robustus</i> (in Millimeters)	256
8. Occipital Curvature Index, Ratio of Lambda-Opisthion Chord (l-o) and Lambda-Opisthion Arc (l-o) in Solo Man (in Millimeters)	257
9. Size of the Foramen Occipitale in Hominids (in Millimeters)	259
10. Size of the Condylus Occipitalis (in Millimeters)	260
11. Distance between Inion (Center of the Occipital Torus) and Internal Protuberance (in Millimeters)	267
12. Diameter of the Apertura Meatus Acustici Externi (in Millimeters)	276
13. Measurements (in Millimeters) of the Foramen Ovale in Solo Man and Modern Man	281
14. Measurements (in Millimeters) of the Fossa Hypophyseos in a Solo Skull and in Modern Man	285

ILLUSTRATIONS

PLATES

(AT END)

16. Excavation of Ngandong Skull VI and scene along the Solo River, near Menden, north of Ngandong
17. Excavation and cross-section through the Ngandong terrace
18. Solo Skull I
19. Solo Skulls I and II
20. Solo Skulls III and IV
21. Solo Skull IV
22. Solo Skull V
23. Solo Skulls V and VI
24. Solo Skull VI
25. Solo Skulls VII and VIII
26. Solo Skull IX
27. Solo Skulls IX and X
28. Solo Skulls X and XI
29. Solo Skull XI
30. Solo Skull XI
31. Solo Tibiae A and B
32. Solo Tibia B
33. Solo Skull XI
34. Solo Skull XI
35. Solo Skull XI
36. Solo Skull XI
37. Solo Skull XI
38. Solo Skull VI
39. Solo Skull XI
40. Solo Skull XI
41. Reconstruction of skull of Solo man
42. Solo Skull VI
43. Solo Skull XI
44. Solo Skull XI, Australian and Tasmanian skulls, Solo Skulls VI and V
45. Endocasts of gorilla, Solo Skull XI, and modern man
46. Key to landmarks on endocasts of gorilla, Solo Skull XI, and modern man shown on Pl. 45
47. X-ray photographs of Solo Skulls VI and XI

TEXT FIGURES

1. Skull bowls. Late Paleolithic, France; modern Ashanti, Africa; Hindu monument, Singosari, Java 216
2. Implements from the Ngandong layers 217
3. Transverse sections through Tibia A and Tibia B 227
4. Mid-sagittal craniogram of Solo Skull VI; outer and inner contours of the braincase . . 229
5. Mid-sagittal craniogram of Solo Skull XI; outer and inner contours of the braincase . . 230
6. Mid-sagittal craniogram of Solo Skull I; outer and inner contours of the braincase . . 230
7. Mid-sagittal craniogram of Solo Skull V; outer and inner contours of the braincase . . 232
8. Mid-sagittal craniogram of Solo Skull IX; outer and part of the inner contour of the braincase 234
9. Mid-sagittal craniogram of Solo Skull X; outer and inner contours of the braincase. . . 234

10. Mid-sagittal craniogram of Solo Skull IV; outer and inner contours of the fragment of the calotte	235
11. Interporial coronal craniograms of Solo Skull VI	241
12. Interporial coronal craniogram of Solo Skull XI	243
13. Interporial coronal craniogram of Solo Skull I	244
14. Interporial coronal craniogram of Solo Skull V; outer and inner contours of the braincase	247
15. Interporial coronal craniogram of Solo Skull IX; inner contour indicated in part	248
16. Interporial coronal craniogram of Solo Skull X; outer and inner contours of the braincase	249
17. Mid-sagittal craniograms of <i>Pithecanthropus robustus</i> , <i>Sinanthropus pekinensis</i> (Skulls III, X, XI, XII), Solo Skulls I, V, VI, IX, X, XI, modern man, European of Nordic race and European of Alpine race	258
18. Interporial coronal craniograms of <i>Pithecanthropus robustus</i> , <i>Sinanthropus pekinensis</i> (Skulls III, X, XI, XII), Solo Skulls I, V, VI, IX, X, XI, modern man, European of Nordic race and European of Alpine race	261
19. Horizontal craniograms marking the minimum and maximum limits of the expansion of the braincase of Solo Skulls I, VI, IX, X, XI, Solo Skull V, and <i>Pithecanthropus erectus</i> II	262
20. Horizontal craniograms marking the minimum and maximum limits of the expansion of the braincases: <i>Sinanthropus pekinensis</i> (X, XI, XII), Solo Skulls I, VI, IX, X, XI	263
21. Mid-sagittal craniograms of Solo Skull XI and modern man (Tasmanian)	264
22. Comparative occipital views (norma occipitalis) of <i>Pithecanthropus robustus</i> , <i>Sinanthropus pekinensis</i> XI, Solo Skull XI, Rhodesian skull, Saccopastore Skull I, and skull of La Chapelle-aux-Saints	268
23. Comparative frontal views (norma frontalis) of <i>Sinanthropus pekinensis</i> XI, Solo Skull XI, Rhodesian skull, Saccopastore Skull I, and skull of La Chapelle-aux-Saints. . . .	270
24. Incline of the frontal bone with regard to the Frankfort Horizontal as shown in mid-sagittal craniograms of <i>Sinanthropus pekinensis</i> , Solo skulls, and modern man (Tasmanian)	271
25. The gradual disintegration of the supraorbital tori in the course of human evolution, as it appears in vertical view.	272
26. Para-sagittal craniograms along the base of the squamosal, tympanic, and mastoid bones (fossa mandibularis and adjacent parts) of Solo Skull XI, <i>Pithecanthropus robustus</i> , <i>Sinanthropus pekinensis</i> XI, and modern man (Tasmanian)	273

INTRODUCTION

ON JULY 11, 1948, Dr. Franz Weidenreich passed away very unexpectedly, leaving behind the uncompleted description of the Solo skulls, on which he had labored with unflagging enthusiasm since September, 1946. He will always be remembered for his work on Peking man, and even those who disagree with him must admire his acute observations, his painstaking and well-balanced descriptions, his love for details, his style, and the enormous range of his knowledge. Weidenreich saw and studied more fossil human material than anyone before him, and this personal knowledge provided him with a deeper insight than the mere study of books and casts. After the tragic loss during the war of the Peking material, the new finds from Java so aroused his interest that he did not wait for the end of the war, when the original material would presumably become available, but he described the casts, which had been forwarded to him for safeguarding, in an extensive publication in 1945.

Weidenreich and the present writer were in close contact ever since Weidenreich's visit to Java in 1938. His enthusiastic reception of each new discovery, his inspiring letters, and his financial aid were of immeasurable assistance in our search for early man, which had only slight official encouragement in its early stages. At his suggestion, I went to Peking from Java in 1939 to study the relationship between *Pithecanthropus* and *Sinanthropus* and to prepare a description of the new *Pithecanthropus* skull of 1937 under his direction. It was in his laboratory in the Cenozoic Research Laboratory in Peking that I learned to appreciate not only his systematic and analytic mind but his honest personality.

Weidenreich left China for New York in 1941. After the end of the war in the Pacific, when he learned that my family and I had survived the occupation in Java and that the skulls were safe, he immediately explored every avenue of assistance to enable me to come to the United States. I am glad that our Javanese material gave him some consolation for the loss of the Peking material, since the Ngandong finds fill the gap between the *Sinanthropus*-*Pithecan-*

thropus and the Neanderthal groups. The study of the Ngandong material undoubtedly gave him greater personal satisfaction than it possibly could to any other student. Fate did not allow him to finish this study. When I had to leave New York in February, 1948, I could not know that we would never meet again. It was with deep personal regret that I learned of his death.

The fossil human remains from Java, which form the principal subject of this publication, were collected between 1931 and 1941, over a period of 10 years. Although the excavations at Ngandong were virtually exhausted towards the end of 1933, Sangiran still remains the most promising site in Java; our activities there were interrupted by the political situation in Indonesia early in 1942.

Since the individual story of each find forms part of the description of the material, it is unnecessary to repeat it here. It is, however, pertinent to give some attention to the fate of the collection during the critical years of the war, and to provide some background for the preparation of the present paper, a task facilitated by the cooperation of many friends and colleagues, the generosity of several scientific institutions, and the support of the officers of the Geological Survey and the Government of the former Netherlands East Indies.

Early in 1942 when I was still in Java, and after the beginning of war with Japan, I received a letter from the East Indies Institute of America (later the Southeast Asia Institute, but now disbanded), together with a memorandum from Dr. Weidenreich and Dr. W. K. Gregory, requesting permission to publish a preliminary description of the most recent finds, casts of which had been forwarded to the former in 1941, and suggesting that this precious material be evacuated. As I was then in military service, it was impossible even to reply.

During the Japanese occupation I was confronted with the difficult task of protecting our finds. For several years during this period the Ngandong skulls were in Batavia in the care of Prof. Dr. E. B. Mijsberg, who because of his numerous official duties was unable to prepare a report. The collection was moved back to the

Geological Survey at Bandung under difficult conditions. Although the Japanese forced us to keep the human fossils in the official safe, we managed nevertheless to exchange several original specimens for well-made casts, and to secrete the former with the material not yet described. One part of the collection remained in the Geological Survey building, interpolated among casts and unsuspected fossils; another portion, especially the newly discovered fossils, were protected by Mrs. L. S. L. von Koenigswald and by neutral friends. In addition to my wife I am deeply obliged to my Swiss colleague, Dr. W. Mohler, who sheltered the *Pithecanthropus* and *Meganthropus* jaws, and to my Swedish friend, Rolf Blomberg, who took care of my Chinese collection, including the only known teeth of *Gigantopithecus*.

The Japanese showed great interest in the fossils. In 1942 we were powerless to prevent them from sending one of the Ngandong skulls, together with some less important material, to Japan as a birthday present for the Emperor. Naturally we regarded the skull as a total loss. However, shortly after my arrival in New York, following the suggestion of Dr. H. L. Shapiro, one of his former students, Lieut. Walter Fairservis, Jr., then with the American military authorities in Japan, became interested in tracing the fossil. Mr. Fairservis carefully followed every possible clue and succeeded in locating the fossil skull in the imperial collections in Kyoto. We are much obliged to Mr. Fairservis, who, with the permission of the Netherlands authorities, personally brought the skull to New York in December, 1946.

After the conclusion of the war in Java, I learned that, except for the Solo skull just mentioned, all the fossil human remains were intact. In the subsequent disturbed period in the Far East, we lost the greater part of our already largely diminished property, so that it was not easy to keep the collection under surveillance. We were virtually isolated, and postal connections were difficult. Dr. Walter A. Foote, American Consul General, very kindly assisted us in communicating with the Carnegie Institution of Washington and the American Museum of Natural History. However, when I approached Dr. Foote, he had already received inquiries as to our whereabouts. Later I learned that Mr. Fairfield Osborn, President of the New York Zoological Society, had made inquiries

about us through the State Department as it had been rumored among our friends at the American Museum that I had not survived.

When Dr. Weidenreich learned that my family and I were alive, he made it possible for us to go to the United States, to live and work under normal conditions, studying and describing the material. Dr. Weidenreich should have full credit for the organization and the success of our trip to the United States. It is a pleasure to express my gratitude to Col. Ir. C. J. Warners, Director of Traffic and Public Works, and to Ir. G. J. Wally, head of the mining service, both at Batavia, as well as Ir. W. C. Benschop Koolhoven, head of the Geological Survey, and to my friend and colleague, Ir. M. E. Akkersdijk, both at Bandung, for permitting this valuable collection to be studied in the United States. I am under special obligation to the Rockefeller Foundation and the Viking Fund, both in New York, which by generous grants made it possible to realize our trip. I am greatly indebted to Mr. H. Marshall Chadwell, Associate Director of the Division of Natural Sciences of the Rockefeller Foundation, and to Dr. Paul Fejos, Director of Research of the Viking Fund, for their understanding of our situation and for assistance in enabling my family to join me during my studies in the United States.

In New York the American Museum of Natural History kindly offered me hospitality and all its facilities: its library, comparative material, and extremely stimulating contact with its staff and associates as well as the assistance of several departments during the entire period of our stay at the Museum. I desire to tender my thanks especially to Dr. Albert E. Parr, Director of the American Museum, Dr. George Gaylord Simpson, Chairman of the Department of Geology and Paleontology, Dr. William K. Gregory, Dr. Edwin H. Colbert (Department of Geology and Paleontology) and Dr. J. H. McGregor (Columbia University). I am under obligation to Dr. Harry L. Shapiro and Miss Bella Weitzner for editing the uncompleted manuscript and preparing it for the press. I remember with gratitude the late Dr. Milo Hellman, who had a deep interest in my studies and offered me valuable advice, especially with respect to the problems of human dentition. I also wish to thank Mr. Otto Falkenbach, who, under a special grant from

the Rockefeller Foundation, skilfully prepared the Ngandong skulls and patiently reconstructed the crushed *Pithecanthropus* skull of 1939; Miss Inger Achton, who is responsible for the excellent wash and line drawings; and Mrs. Rachel Nichols for her active assistance in the preparation of this manuscript. Dr. H. L. Shapiro and Dr. R. Spillman kindly aided in making X-ray photographs of several specimens, a difficult task as the material is heavily fossilized.

We came to New York intending to stay one year. However, having been a prisoner of war under the Japanese in Java, my health was so poor that it soon became evident that one year was too short a period in which to recuperate. In addition, the material was so rich that it was equally obvious that it would be impossible to complete our studies within that period. A second year in the United States was generously made possible for me and my family through grants from the Viking Fund, the Carnegie Institution of Washington, and the American Philosophical Society. I am greatly indebted to Dr. Paul Fejos, Director of Research of the Viking Fund, who repeatedly and most cordially offered us his help, to Dr. V. Bush, President, and Mr. Paul A. Scherer, Executive Officer, of the Carnegie Institution of Washington, to Dr. A. V. Kidder of its Division of Historical Research, and to Dr. Luther P. Eisenhart, Executive Officer of the American Philosophical Society. Before the end of the second year it became imperative that I interrupt my studies in New York in order to assume my new responsibilities at the University of Utrecht.

In January, 1947, I had the honor of attending the Conference for Genetics, Palaeontology, and Evolution, part of the Princeton University Bicentennial. For making it possible to include more of the field of genetics in my studies, I have to thank Prof. Th. Dobzhansky, Columbia University, and especially Dr. M. Demerec, Director of the Biological Laboratory, Carnegie Institution of Washington, at Cold Spring Harbor, who kindly offered me a place in his laboratory during the hot summer of 1947. I recall with much pleasure the intellectual atmosphere and idyllic surroundings at Cold Spring Harbor.

When I arrived in New York from Java, I found that Dr. Weidenreich in his extensive

study of the *Sinanthropus* skulls had already referred to the new *Pithecanthropus* skull, which I had taken to Peking in 1939. In 1941 we had managed to send a cast of the *Meganthropus* jaw to New York as a proof of the discovery and as a precaution against the loss of the original during a possible war in the Far East. I learned also that the casts of the *Gigantopithecus* teeth and of the newly discovered jaws had also been discussed and illustrated by Weidenreich in several publications. One of these,¹ an extensive comparative study, is not always accurate, based as it was upon casts. Its geological sections can bear revision. Nevertheless, since this detailed study anticipated the conclusions to be drawn from the new finds, comparatively little can be gained by describing the original specimen.

Our collection of human fossils from Java contained remains from every horizon of the Pleistocene, and comprised more finds than were expected. It was no minor undertaking to prepare a detailed description within the limited time available. Before I left Java we had agreed that the study of the material should be undertaken in collaboration with Dr. Weidenreich, who had assisted me with funds and advice, and for whose unsurpassed morphological knowledge we all had the highest esteem. To make the best possible use of our time it was necessary to divide the material. It is only natural that Dr. Weidenreich, who had so recently completed the description of the *Sinanthropus* skulls (the original material was tragically lost during the war), became responsible for the description of the skulls, especially the Ngandong skulls, previously known only through rather preliminary descriptions. I assumed responsibility for the description of the jaws and teeth, the history of the discoveries, and the stratigraphical position of the finds. For many years the evolution of the human dentition had been a special subject of my studies, and for this reason I had gathered a large collection of modern human teeth from Java. I have spent considerable time in working out certain principles of the dental morphology, but it seemed better to exclude these general descriptions from this monograph and publish them separately in the future. I am deeply obliged to Dr. Weidenreich for his advice, his patience, and many stimulating discussions.

¹ Weidenreich, 1945.

The reader will find that Dr. Weidenreich and I disagree on several points. This is only the natural result of our extremely different backgrounds. The anthropologist, studying man, especially recent man, may draw attention to specific morphological details that easily escape the paleontologist, but, on the other hand, he tends to neglect or underestimate the stratigraphical facts. The paleontologist primarily

thinks in terms of time and sees evolution, the very core of his studies, as a unit against the background of geologic history.

Human evolution is a complex problem. It must be approached from different directions, and I sincerely hope that this publication will contribute to our knowledge of our own evolution.

HISTORY OF THE DISCOVERY

From Surakarta in central Java the Solo River, now called Bengawan Solo or "Great River Solo," flows eastward, following the southern border of the Kendeng Hills until it reaches Ngawi, where it joins the Madiun River. From here it turns northward, following a pre-existing valley through the low Kendeng Range which at this point is only about 10 miles wide.

Here the Kendeng Range separates the fertile plain of Madiun in the south from that of Bodjonegoro in the north. Both regions are densely populated. The Kendeng consists of folded Miocene and Pliocene marls and sandstones, with some limestone beds, and is unsuitable for the cultivation of rice. Consequently, the region is covered by enormous teak forests (*djatti*). Except for a few hamlets along the Solo between Ngawi and Menden it is virtually unpopulated.

Directly west of Ngawi is Trinil, the site made famous by Dubois, where the first *Pithecanthropus* skull was discovered in 1891. Dubois was interested mainly in fossils, but the German Selenka Expedition which worked in Trinil from 1907 to 1908 was also concerned with problems of stratigraphy. We are indebted to G. Elbert, a member of this expedition, for the first details concerning the geology of the site and its surroundings.

In the course of his work Elbert also observed river terraces, "north of Trinil," recognizing them as more recent than the classical Trinil layers. He mentions a high terrace 14 to 17 meters above the Solo River, which he believed represented the Middle Pleistocene—Trinil belonging to the Lower Pleistocene.¹ In his publication he mentions a site called

"Bangoen" from which he has an *Elephas* molar. No place of this name is known, but he may have meant Ngandong, which is only a few kilometers south of Ngrawoh.

The material collected by Elbert was described by Soergel, who also listed Elbert's sites for the first time.² Of these, "Ngrawoh, north of Ngawi" is situated on the above-mentioned terrace, as is "Pandejan," if the latter locality is identical with that worked by the Geological Survey not far from Ngawi. However, it may not be the same site, as there are several places with this name in the area. The name Pandejan is quite common.

Since Elbert's publications, on the whole, contained too much theoretical matter and were adversely criticised, his observations were not generally accepted. In fact, his discovery was virtually forgotten until August, 1931, when the late C. ter Haar, a member of the Geological Survey, rediscovered the terraces during a routine mapping of sheet No. 92, Randublatung.

Ter Haar immediately recognized the importance of the site, from which he brought back a series of fossil bones, among them a fine water buffalo skull. In September, 1931, the Survey began excavations which were continued until the end of November, 1933. In the course of these operations over 25,000 mammalian remains were excavated, among them the fragments of 11 (perhaps 12) human skulls and two tibiae.

Ngandong lies on the left bank of the Solo River about 6 miles north of Ngawi, farther west from it than Trinil. Only a few small footpaths traverse the forest; consequently the easiest way to reach Ngandong is by water,

¹ Elbert, 1908, 658.

² Soergel, 1914, 2.

either from Ngawi or Tjepu, from which points many native boats move up and down the river, transporting wood and rice.

During the dry season the Ngandong terrace is about 20 meters above the level of the Solo. The terrace deposits have been largely destroyed by erosion and are preserved only in a few places. In Ngandong the deposit reaches a maximum thickness of about 3 meters, with the greatest accumulation of fossils at the base, within the first meter from the bottom. The deposit, consisting of sand and gravel, contains a great quantity of volcanic material. The top layer seems to have been formed in part by the debris from the surrounding Tertiary rock; thus the underlying terrace remnant is protected from erosion.

The most important finds at Ngandong are the remains of man. Various accounts of this discovery have been published. According to an official report by the late C. ter Haar, the first two skull fragments, discovered on September 15 and September 30, 1931, respectively, were registered by our native collectors as "tiger skull" in the first case and "ape skull" in the second. They were sent to Bandung with other material and were there recognized as human remains. Skull I was first partially prepared by Mr. Oppenoorth, without the help of our preparator. After expert preparation, the present condition of the skull is very different from what might be expected from these first photographs.

From October 21 to October 30, 1931, Mr. Oppenoorth, as Acting Director of the Geological Survey, made a field trip to Ngandong to visit the site where the two skulls had been found. He personally brought back Skull III to the Survey (its number, therefore, does not occur in the original register kept by our Indonesian collectors). The skull was quite broken, and its reconstruction was apparently not very accurate. When this specimen was cleaned in the American Museum we found attached to it part of a parietal bone which certainly belongs to a different individual and which we have numbered IIIA.

Skull V was discovered on March 17, 1933, and was recognized as human by our Indonesian collectors who cabled to Bandung. Mr. Oppenoorth went to the site, where he excavated the skull on March 21. He published

photographs showing it in its original layer.¹ According to these photographs the skull was resting on its vault.

The skull was crushed, and a large crack was visible. Towards the rear of the left parietal, a small triangular piece of bone had been driven several millimeters into it. A photograph of the specimen after preliminary cleaning was published by Oppenoorth.² Later the skull was restored to its original shape. The area surrounding the break was darker than the rest of the specimen; our Indonesian assistants attempted to explain this discoloration as traces of blood.

Our collectors also recognized Skull VI as human and therefore cabled to Bandung. This time ter Haar and I went to the site to excavate the find. Having discovered the skull, our collectors had carefully covered it with sand and marked the place with leaves. The conditions under which we found and excavated the specimen are illustrated in Pl. 16a. Like No. V, this skull was resting on its vault. The surface was partly covered by some encrustations. In the surrounding area we found a few broken deer antlers but no additional human remains. The state of our excavations at that time is illustrated in Pl. 17a.

Skull VII is a small fragment which was brought to light in Bandung. No. VIII consists of the two parietal bones that were discovered separately, but are without doubt part of the same skull. The bones were left in place by the collectors, and I removed them September 8, 1933.

There are two human tibiae in the collection. The label of one of them is damaged so that the exact date of excavation is unknown, but it was found some time in 1932. Only one tibia was known to Oppenoorth.

It is evident from this list that the human remains came to light regularly throughout the whole period of excavation and that they were found neither in one particular spot nor in a special layer but were irregularly distributed throughout the whole site. Two skulls, IX and X, were found on the same day.

Two peculiarities demand some explanation: one, the strange condition of the finds, and

¹ Oppenoorth, 1932c, 274, Fig. 7; 1932b, 109, Fig. 5.

² Oppenoorth, 1932b, 109-110.

the other, the curious selection. While every part of the skeleton of the various animals was found, especially of the banteng and the deer, the collection of human remains, which includes only incomplete skulls and tibiae, must be regarded as artificial. We should note here that we searched especially for other parts of the human skeleton and even despatched a special team to hunt for isolated human teeth, but no trace of such remains was found.

A clue to the unusual selection of human remains may perhaps be found in the damaged condition of the skulls. Of these II, VII, and VIII are only small fragments. Of the more complete skulls, I, V, and X, the area

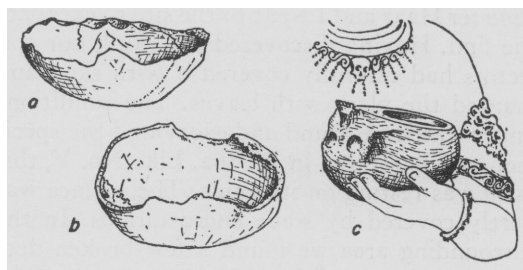


FIG. 1. Skull bowls. a. Europe, late Paleolithic, Grotte du Placard, France. b. Africa, modern Ashanti. c. Java, from a Hindu monument, Singosari, Java.

around the foramen magnum is either damaged or completely missing. In Skulls VI and XI the bone around the foramen magnum is complete, but the fore part of the skull is damaged. When laid upside down on a table, Skulls I, III, V, IX, and X give the impression of being primitive skull bowls.

There is an ancient general belief that there are secret powers situated in human skulls and bones, and these are often used by primitive people for ceremonial or magical purposes. Head hunting is a widespread custom. As can often be observed in certain skulls, especially from Borneo and New Guinea, the base around the foramen magnum has been broken in order to remove the brain, which is then consumed in the belief that it will instill the powers of the former owner.

This belief probably reverts to the time of *Sinanthropus* from China. All the skulls found there have damaged bases. There are also, according to Weidenreich, other signs of cannibal-

ism to be observed. Neanderthal man of Europe practised cannibalism at Krapina, where the burnt and damaged bones of numerous individuals have been found. Neatly trimmed skull bowls occur in Europe at the end of the Ice Age in the Magdalenian of Laugerie Basse and du Placard. Skull bowls (Fig. 1) seem to have been used in Java during the Hindu period, according to the evidence offered by certain bronzes and stone carvings. Even in medieval Europe skulls of saints were sometimes worked into skull cups. These have reached their greatest perfection today among the Mongols of northern China, where they can be found in large quantities in almost every Mongolian temple.

In addition to the skull cups, skull fragments and other human bones are often made into amulets or used as charms. In primitive societies, human bones are sometimes kept by members of the family or tribe as protective charms. The Dayak of Borneo often decorate their swords with parts of the skull and other human bones. Human skulls are used to mark places that are taboo in New Caledonia, or are placed on sticks and set out along the trails to warn foreigners and keep strangers out, as in New Guinea.

We see that there are many reasons that might influence primitive man in attaching special significance to the skeletal remains of his own species. Neanderthal man in Europe even buried his dead, placing implements and tools in the grave for use in a better world. Under these circumstances it is not astonishing that Solo man seemed to have developed a particular interest in human bones, and very probably practised head hunting. The selection of human bones in Ngandong is surely not the work of nature. The bones and skulls were brought to that place by man and either were left there purposely or, more probably, were lost during quarrels or sudden floods.

We must confess that very slight evidence of human habitation was observed. It is very probable that the enormous accumulation of bones in Ngandong is due to human activity, but no traces of fireplaces or any large quantity of implements was found. Only a few small stone scrapers and some triangular chalcidony flakes were observed, but they have disappeared from our collection. Some spines of rays, unexpected in a terrestrial deposit, may be ex-

TABLE 1
LIST OF THE HUMAN REMAINS FROM NGANDONG

Number	Excavation Number	Date	First Description
1931			
Skulls			
I	29	September 15	I-III Oppenoorth, 1932a, 57-61
II	195	September 30	
III	272a	October 13	
1932			
IV	3493	January 25	IV-V Oppenoorth, 1932b, 108-112
V	7594	March 17	
VI	9975	June 13	(VI) Photograph of the cast, Dubois, 1937a
VII	9775	May 24	
1933			
VIII	{ 19109	August 22	Photograph of the entire collection, von Koenigswald, 1937, 32
	{ 19587	August 30	
IX	21331	September 27	
X	21332	September 27	
XI	22205	November 8	
Tibiae			
A	?	? 4, 1932	
B	14518	January 17, 1933	

plained as having been used as weapons, possibly as daggers or arrowheads. Such spines are frequently used by primitive people for similar purposes, especially in the South Pacific (Fig. 2).

At Sidoredjo near Watualong in the Ngandong horizon we discovered a bone spearhead which, to judge from its form, might be a copy of such a spine. A photograph of this was published by Van Stein Callenfels in 1936. However, he erroneously gives the site as Ngandong. I cannot agree with the interpretation of Callenfels and Oppenoorth that this implement is a harpoon, for it has no feature suggesting an attachment for a line. There is no relationship between this bone implement and the European Magdalenian type.

A few deer antlers from Ngandong may have

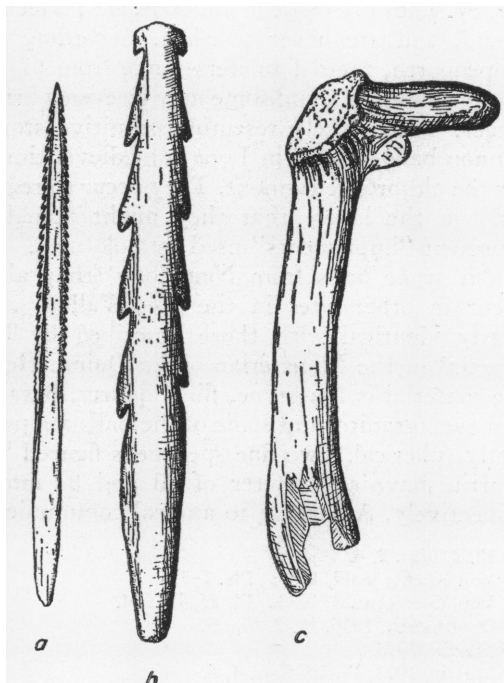


FIG. 2. Implements from the Ngandong layers. a. Spine of a ray, probably used as a weapon. b. Spearhead, carved of bone, Sidoredjo, west of Ngawi. c. Deer antler used as a kind of ax or club, Ngandong.

been used as axes. The best example has been published by Callenfels and subsequently by Oppenoorth, but I cannot agree with the latter that the two antlers from Ngandong published by him in 1936¹ are worked by man. Callenfels' Fig. 2, identified by Oppenoorth as a haft, has not been worked by man, as is evident from the piece of skull still attached to the antler. I must confess that it is impossible for me to see in it a carved bird's head, as suggested by Oppenoorth.

The large tiger skull from Ngandong published in 1933,² may have been damaged by man, and the injuries on certain deer antlers³ might also be artificial. All these deposits contain a great number of bones that have been broken as the result of being tossed around on the river bed or of damage by crocodiles or man. Only a very few of these bones may have been used. After a careful study of the region, I cannot agree with Oppenoorth when he labels a whole collection of broken bones as "implements." The use of this term suggests an advanced bone culture which is certainly nonexistent. The most interesting specimen illustrated by Oppenoorth is a stone ball from Ngandong.⁴ Similar stone balls have been found at several places in our excavations in the Solo Valley. They are made of andesite, are perfectly round, and are never polished. According to Oppenoorth, their diameters range from 67 to 92 mm. (not cm.), and some may be even a little larger. They closely resemble primitive stone cannon balls as used in Java in medieval times for the old bronze cannons. They occur so regularly in the layers that they might actually represent "implements" used by Solo men.

Our stone balls from Ngandong (they also occur in other sites in the Solo Valley) are nearly identical with those described by H. Martin⁵ in the Mousterian of La Quina. Here the material is limestone, flint, quartz, basalt, and even granite, and some of the balls are perfectly spherical. Two fine specimens figured by Martin⁶ have a diameter of 73 and 83 mm., respectively. According to an oral communica-

tion from Henry Field such balls also occur in the Mousterian of Techik Tach in Russia. From the Mousterio-Levalloisian of Florisbad, South Africa, Dreyer and Lyle⁷ mention "dozens of round balls" about 3 inches in diameter made mostly of dolorite, and also a few of blue shales.

The earliest occurrence of such stone balls seems to be in the Acheulean of Olorgesailie in Kenya, East Africa. Leakey⁸ reported from there, "We have found a number of round stone balls, some isolated, but in many cases in groups of three strongly indicating the use of the bolas, still used as a hunting weapon in South America." Unfortunately, none of these are illustrated, nor is anything said as to whether these balls are merely round stones or have been artificially shaped like the stone balls from Ngandong and Europe.

Such balls have a wide distribution in the Paleolithic, especially the Mousterian period. Their use is unknown, but most probably they were sling stones or bolas. Their occurrence in Ngandong would perhaps permit us to assume influence from the Mousterian culture which might be otherwise indicated in the typical flaked implements collected in Ngandong. Only flaked implements are known from the Ngandong terrace where not a single hand ax or biface, such as occur in the southern mountains, has been found.

That the human remains from Ngandong were contemporary with the laying down of the sediments is evident from their preservation which is exactly the same as in the numerous animal bones found in the same deposit. Searching for bones, our Indonesian collectors found recent or prehistoric remains of humans at various places in the Solo Valley, also on the opposite bank of the river between Ngandong and Ngrawoh and near Getas where they even excavated an old Chinese cemetery; but in all these places the bones were always quite different and much lighter and could not be mistaken for fossils.

The greater part of the terrace near Ngandong has already been destroyed by erosion, and the remaining areas are virtually all excavated, except for a small section that was left

¹ Pl. 2, Figs. 2, 4.

² Von Koenigswald, 1933a, Pls. 1-3.

³ Von Koenigswald, 1933a, Pl. 25, Fig. 14.

⁴ Oppenoorth, 1936, Pl. 2, Fig. 5.

⁵ Martin, 1923.

⁶ Martin, 1923, Pl. 16, Figs. 4, 5.

⁷ Dreyer and Lyle, 1931.

⁸ Leakey, 1946.

untouched so that the site might be reexamined in the future.

The conditions under which the sediments were laid down are difficult to reconstruct. Most probably a large sand bank in the bend of the river was uncovered during the dry season. Here Solo man camped, for such a situation gave him a double advantage: it would afford him protection against ferocious animals and also place him in an excellent position to hunt animals that came down to the water. During the wet season the bank was flooded and the

bones left were covered with sand and gravel. The human remains were left there either deliberately or accidentally.

The Solo River as it appears today during the dry season is shown in Pl. 16b. A sand bank rises from the river. It may have been just such a spot that was used in former days. It is possible that such locations were more often preferred by primitive man during the Paleolithic, which resulted in the unusual accumulation of paleolithic stone implements, especially hand axes, in many Pleistocene river deposits

GEOLOGY AND PALEONTOLOGY

There are at least three terrace systems in the Solo Valley north of Ngawi. The lowest is about 2 meters, the second about 7 meters, and the Ngandong terrace about 20 meters, above the river, on which the sites of Ngandong, Ngrawoh, and Pandejan are situated. To the north, beyond the limits of the valley, lies the site of Kuwung which may in part be more recent. Collectors searching there for stone implements found an antler fragment of *Cervus* (*Rucervus*) *eldi*, a species of deer still living in northern Malakka, Siam, and Indo-China, but extinct in Java. It occurs in Java only in the neolithic of Sampung, south of Madiun, but has never been observed in the Ngandong terrace.

The Ngandong fauna has also been found at the southern border of the Kendeng, west of Ngawi. There were fossil localities at Sidoredjo, Sembungan, and Ngasinan, but the best was at Natualang. In the excavation of Pitu the Ngandong layer was observable on top of the Trinil formation.

The fauna (Table 2) does not include as many species as one would expect from the enormous quantity of bone material that was excavated. More than two thirds of the finds consist of the remains of deer and cattle. Of all forms, the banteng is perhaps the most common. Fine skulls, the lower jaws still attached, and complete vertebral columns have been found. The fossil form is very close to the living, varying only in a lesser sexual differentiation of the horns. While the horns are quite weak and reduced in the living females, we find no such marked differences in the numerous fossil skulls, all of which certainly do not represent males.

The water buffalo was heavier than the living species and had larger horns. The horn cores form an almost perfect semicircle, with a span of over 2 meters from tip to tip. In the largest specimen, which comes from Ngrawoh, the spread is 2.25 meters.

A common form is an axis deer, which I have described as a subspecies of the living Indian form, but which should perhaps be referred to *Cervus javanicus*. It has, as a regular feature, a small accessory tip in the angle between the

TABLE 2

THE MAMMALIAN FAUNA OF NGANDONG (REVISED)

Carnivora

- Felis palaeojavanica* Stremme
- Panthera tigris* (Linnaeus) var.
- Panthera pardus* (Linnaeus)

Perissodactyla

- Rhinoceros sondaicus* Desmarest

Artiodactyla

- Hexaprotodon ngandongensis*, new species
- Sus macrognathus* Dubois
- Sus brachygnathus* Dubois
- Sus terhaari* von Koenigswald
- Sus* ex. aff. *vittatus* Müller and Schlegel
- Muntiacus muntjac* Zimmermann
- Cervus* (*Rusa*) *hippelaphus* Cuvier
- Cervus javanicus* von Koenigswald
- Bos* (*Bubalus*) *bubalis palaeokerabau* Dubois
- Bos* (*Bibos*) *banteng palaeosondaicus* Dubois

Proboscidea

- Stegodon trigonocephalus* Martin
- Elephas* cf. *namadicus* Falconer and Cautley

Primates

- Homo soloensis* (Oppenoorth)

beam and the brow antler. Such a tip is also typical for *C. (R.) eldi*, but here the beam and the brow antlers form a straight line, while in the Javanese species they form a distinct angle. Furthermore, in the latter form the small tines show a tendency to duplicate as in the barasinga. Less abundant is the water deer, *Cervus hippelaphus*, which is indistinguishable from the living species. The muntjak is rare. Though its antlers are generally longer, it is otherwise indistinguishable from the recent form.

In my first report I also mentioned the small *Axis lydekkeri* as occurring in Ngandong. Further study of the finds (a lower jaw and an isolated molar) revealed that these specimens belonged to the muntjak, and that the first determination was incorrect.

Sus brachygnathus and *Sus macrognathus*, both very common in Trinil, are rare in Ngandong where *Sus terhaari*, a species with a very elongated last lower molar, occurs. All these pigs belong to the *verucosus celebensis* group, while presence of the *vittatus* group is indicated only by a single lower canine.

Tiger and panther are very rare. According to a more recent study by Brongersma, both tigers described by me as *Felis palaeojavanica* and *Felis tigris soloensis* are subspecies of the recent tiger.¹ I believe that the differences in size are too great to be explained merely as sexual differences. The occurrence of two subspecies in one site is not very likely, but I have no recent material at my disposal to help settle this question.

The rhinoceros is identical with the living one, except that it is generally heavier, as is true of so many Pleistocene species.

The hippopotamus seems to be close to the Indian *namadicus* and *palaeindicus*. The species is hexaprotodont, with the first and third incisors enlarged and the second reduced to about half the size of the latter. The canines are large, and the body of the mandible is very high. The eyes are elevated, as in extreme forms of *amphibius*. In my earlier paper I referred this species to Dubois' still undescribed *Hexaprotodon sivajavanicus*, but as Dubois had no material from the terrace deposits and since the species is clearly distinct from the earlier forms,

this determination should be changed to *Hexaprotodon ngandongensis*,² new species.

Remains of proboscideans occur regularly. They belong to two separate genera, *Stegodon* and *Elephas*, the former outnumbering the latter by about three to one. The *Stegodon* is relatively small, no higher than the living Sumatran elephant. A complete skeleton reconstructed from several individuals is exhibited in the Geological Museum in Bandung. I have published a photograph of this reconstruction. It seems to be more highly specialized than the *Stegodon* of Trinil, having a larger number of ridges in the teeth. The *Elephas* is a very large form and quite close to, perhaps even identical with, the Indian *Elephas namadicus*. As the Indian species has a very curious forehead, and since the forehead has not been preserved in any of our Javanese specimens, we are not sure that the Javanese form is identical with it. However, there is no difference in the dentition.

The diagnostic fossils for the Ngandong fauna are *Sus terhaari* and *Cervus javanicus*. Both forms are readily recognizable; neither has ever been found in any other horizon.

As a whole, the Ngandong fauna is lacking in all the more primitive groups that are typical of the older horizons. The carnivores are of the modern type, and there are no longer any antelopes. The hippopotamus and the proboscideans are highly specialized, while cattle and deer are virtually all identical with species still living in Java. The geological position is surely in the late Pleistocene, which is very imperfectly represented in Java. There is a hiatus between the Ngandong fauna and the neolithic fauna of Sampung in south Madiun. The latter fauna still contains several species now extinct in Java, such as *Cervus (R.) eldi* and *Neofelis nebulosa*.

In the illustration (Pl. 16b) the two main terraces, those at 7 and at 20 meters, along the Solo are shown. Tropical erosion has largely destroyed the gravel deposits on these

¹ Brongersma, 1935, 56.

² This new name is here introduced to emphasize the fact that the *Hexaprotodon* from the Ngandong layers must be regarded as a distinct species. A full description will be published in the Proceedings of the Royal Netherlands Academy of Sciences (Koninklijke Nederlandse Akademie van Wetenschappen), Amsterdam.

terraces so that most of them can be recognized only by their morphology. As the Kendeng Hills are elevated, these terraces indicate quiescent periods during which no erosion occurred, and the river bed was more or less stable. Therefore, they cannot be correlated with any change in the sea level, as can the various terraces in Europe and other parts of the world.

No conclusions as to the climatic conditions can be drawn from the mammalian fauna. However, the water buffalo has a much wider horn spread than either the buffalo from the Trinil horizon or the living Javanese buffalo. It is difficult to imagine these animals flourishing in a dense tropical jungle, and their presence may indicate a more open grassland like that on the smaller Sunda Islands.

The few remains of birds from Watualang, which are contemporaneous with Ngandong fossils, have been studied by Wetmore. He

describes¹ a metatarsus of a big black stork, *Leptophilos titon* Wetmore, fragments of the ulna and the radius of a vulture, and the humerus of a crane, *Grus grus* (Linnaeus). This last form is especially interesting.

There are no records of the occurrence of the crane in Java, and at the present time it winters south only to the Yangtse Valley, Hainan, Swatow, and northern India. Pleistocene conditions apparently carried it much farther north and its occurrence in Central Java is of particular interest in its possible indication of climatic conditions of the period from which it comes.²

If this is true and a relation between the Ngandong and Mousterian culture is also accepted, the Ngandong deposit would belong to the last glacial rather than to the last interglacial period.

¹ Wetmore, 1940.

² Wetmore, 1940, 450.

MORPHOLOGY OF SOLO MAN

EUGÈNE DUBOIS AND SOLO MAN

THE HISTORY OF PALEONTOLOGY, particularly human paleontology, is replete with errors and misjudgments. This is inevitable and excusable. No one will criticize the Swiss scientist Scheuchzer who, in 1716, described the skeleton of a Miocene giant salamander as "the sad bones of a poor sinner who was drowned in the Flood." We can hold up to scorn those laymen who insisted that a skeleton found in a limestone cave in the Neanderthal Valley was that of an old tramp who, tormented by chronic arthritis, perished at the roadside during the war against Napoleon I and not that of an extinct form of man. Nor will anybody censure Eugène Dubois for his initial indecision as to whether the skull cap of Trinil man was that of a fossil chimpanzee or a large fossil gibbon. One may also grant indulgence to those authors who adhered to their own interpretations even when new and more complete finds proved them incorrect.

But the limit of tolerance for these human foibles is attained when the proponent of a questionable scientific doctrine endeavors to maintain it against all possible odds by misrepresentation, misinformation, and the suppression of contradictory data, and by insinuating unfairness in opponents of his views. I regret that I find it necessary to accuse Dubois of such an attitude. Dubois himself has passed away, but his published work still stands. Many scientists, and in particular many anthropologists lacking judgment in matters of comparative human anatomy, regard him as an authority on human paleontology and may still believe in the validity and infallibility of his statements and claims. This reputation, I am certain, will be considerably altered when his peculiar methods of dealing with all the finds of fossil man in Java become better known.

Solo man was discovered in 1931 by a geologist, Dr. C. ter Haar, and announced by the geologist W. F. F. Oppenoorth.¹ At that time one skull (I) only was complete enough to permit a fair judgment of its general morphological character. As described by Oppenoorth, the skull consists of a nearly complete calvarium,

with all the facial parts missing. The nuchal plane and the foramen magnum with the right condyle were intact. In Oppenoorth's plates (I to V), the skull is illustrated in five positions: norma lateralis, norma verticalis, norma basilaris, norma frontalis, and norma occipitalis. The illustrations reveal as characteristic features two heavy supraorbital tori united by a well-developed glabellar torus, a flat receding forehead, and a marked postorbital constriction, a pronounced continuous occipital torus, and a remarkably sloping nuchal plane with deep muscular impressions. Above the glabella-inion plane, the calvarium is low, coinciding almost entirely with the corresponding curve of the Neanderthals, as illustrated by Oppenoorth in a mid-sagittal diagram (his Fig. 1). From all these similarities Oppenoorth concluded that Ngandong Skull I is a Neanderthal type, but he also noted that the nuchal plane recalls the condition of the Rhodesian skull. In ensuing publications,² Oppenoorth maintained this opinion. Skull V, discovered in the meantime,³ gave additional support to the accuracy of his first classification. But Dubois intervened. In a short letter to the editor of Nature he wrote:

A careful study of Oppenoorth's paper leaves little doubt, however, in my mind that Ngandong man and Wadjak man are one identical type.⁴

Dubois (1921) had classified Wadjak man as a fossil "*Homo sapiens*" very close to Australians and Tasmanians. He based this claim of relationship on the identity of some essential cranial measurements: The average calvarial height index is 53 in Australians, 56.1 in Tasmanians, 52 in Wadjak I; the average of the glabella-bregma angle is 54.8° in Australians, 56° in Tasmanians, and 54° in Wadjak I. Oppenoorth had calculated the height index in Ngandong Skull I as 44.5 and its bregma angle as 45.5°. These indices are considerably lower than those of the Wadjak skull, but fit any

² Oppenoorth, 1932b, 1932c.

³ Illustrated in Oppenoorth's second paper, cf. 1932b, 109.

⁴ Dubois, 1932, 20.

¹ Oppenoorth, 1932a.

existing Neanderthal type. Dubois disregarded these facts, although he referred expressly to Oppenoorth's statements, arguing that the Ngandong skulls and the Wadjak skull were identical. The lateral, frontal, and vertical views of Ngandong Skull I illustrated by Oppenoorth, when compared with the corresponding views of the Wadjak skull published by Dubois,¹ incontestably prove that Dubois' claim is without any foundation.

Despite the discoveries of additional Ngandong skulls, particularly Skull VI, the base of which is almost entirely preserved and which Dubois himself illustrated in 1936 (his Pl. 2), he persisted in this contention and finally in 1937 influenced Oppenoorth to nullify his earlier statements of 1932 regarding the morphological character of Solo man. Now Oppenoorth stated:

... the structure of these [Ngandong] skulls has such modern traits that the resemblance with Neanderthal man is only seeming [italics mine]. And yet considering the only limb bone found, a right tibia, the characteristics of it will strengthen this conclusion.²

This is the phrasing of Oppenoorth's revocation:

In my first publications I proposed to unite *H. soloensis*, *H. rhodesiensis*, *H. wadjakensis*, all proto-australian forms, into a separate subgenus, *Javanthropus*, but—and I completely agree with Dubois that they all belong to this group—that name was not well chosen and it is better to drop it. Yet we have in *Homo soloensis* the oldest at present known representative of *Homo sapiens fossilis*.³

In 1937, when Oppenoorth apparently yielded to Dubois' pressure, five skulls, in addition to the six skulls described in his first publications (1932), were known. Among the new finds, in addition to the negligible small skull fragments VII and VIII, were Skulls IX, X, and XI, the last an almost complete and intact calvarium. There were also not only a single tibia, as recorded by Oppenoorth and Dubois, but two—both right ones. Apparently neither Oppenoorth nor Dubois ever had an opportunity to study this new material. In his publications⁴ directed against von Koenigswald and me, Dubois repeated his previous conten-

tions at great length. As may be judged from the succeeding paraphrase of his text, he had not shifted from his previous point of view. He considered that *Pithecanthropus* should be ranked with another genus rather than with *Gorilla*, *Simia*, and *Homo* and that its skull cap is more like the latter in absolute size and vaulting, and shows closer agreement with *Anthropopithecus* (chimpanzee), and in its form still more with *Hylobates* (gibbon).⁵ Dubois concluded with the following words:

It is most regrettable that for the interpretation of the important discoveries of *human* [italics Dubois'] fossils in China and Java, Weidenreich, von Koenigswald and Weinert were ... guided by preconceived opinions and consequently did not contribute to, on the contrary they impeded, the advance of knowledge of *man's place in nature*. ...⁶

Dubois was not "guided by preconceived opinions." In the three parts of the paper published in 1940, he claimed that *Sinanthropus pekinensis*, *Pithecanthropus* Skulls II, III, and IV (later named *Pithecanthropus robustus*), and *Homo soloensis* are all representatives of *Homo sapiens fossilis* and identical with "his" Wadjak man. According to Dubois' final statements, "his" Trinil calotte of *Pithecanthropus* (Skull I) is not a *Homo* but a giant gibbon, similar to man yet not connected with him by transitional forms; it has mutated by a sudden leap to modern man. To demonstrate how Dubois "proved" these identities, it suffices to examine his method of dealing with the upper jaw of *Pithecanthropus* Skull IV. Von Koenigswald and I first described the jaw briefly in *Nature* in 1939. I reverted to it in a tentative reconstruction of the skull in 1940. Dubois reproduced the illustrations of this reconstruction and of the upper jaw in the first part of his publication and again that of the upper jaw in our *Nature* article in the second part.⁷ He also reproduced his own illustrations of the Wadjak upper jaw II in both papers. However, he did not discuss the characteristic differences in the size and form of the dental arcs, and in the size, arrangement, and pattern of the teeth. He even dismissed the astonishing fact that there is a wide maxillary diastema in the *Pithecanthropus robustus* jaw, a feature never previously observed in any

¹ Dubois, 1922, Figs. 1, 2, 3.

² Oppenoorth, 1937, 357.

³ Oppenoorth, 1937, 358-359.

⁴ Dubois, 1940.

⁵ Dubois, 1940, 1269.

⁶ Dubois, 1940, 1275.

⁷ Dubois, 1940.

hominid jaw. Dubois tacitly passed over all these peculiarities and continued to insist that *Pithecanthropus* Skull IV is not a "*Pithecanthropus*" but a "Wadjak man."

In the passage quoted above, Dubois accused von Koenigswald, Weinert, and me of impeding the advance of knowledge by rejecting his ideas. But he failed to include in his list Davidson Black and Marcellin Boule. Davidson Black said: "It is clearly evident that the crania of *Sinanthropus* and *Pithecanthropus* resemble one another much more closely than they do any other known hominid type,"¹ while Marcellin Boule² was so convinced of the identity of *Pithecanthropus erectus* and *Sinanthropus pekinensis* that he proposed discarding the term "*Sinanthropus*" and suggested that Peking man be called "*Pithecanthropus pekinensis*. During

his entire life, Dubois was obsessed by the firm conviction that "his" *Pithecanthropus* was a gibbon and "his" Wadjak man the only fossil hominid form that had ever existed in Java. Reverting to Dubois' contention that von Koenigswald and I have impeded the progress of knowledge with regard to man's evolution, it should be noted that Dubois found the Trinil skull cap in 1891, but his first paper, presenting photographs and a detailed description, was not published until 1924, 33 years later. The Wadjak skeletons were delivered to Dubois by their discoverer in 1890, but Dubois' publication dealing with these finds appeared 31 years later, in 1921. In the long years between discovery and publication, Dubois had all the materials under lock and key, preventing scientists from even seeing them.

THE MATERIAL AS DESCRIBED BY W. F. F. OPPENOORTH AND OTHERS

The human finds of Ngandong comprised 11 calvaria and calvarial fragments and two right tibiae. Of this material only six calvaria and fragments, namely, Skulls I, II, III, IV, V, and VI, and one tibia, in the official catalogue designated as Tibia B, were mentioned or described by Oppenoorth. The five remaining calvaria, VII, VIII, IX, X, and XI, and the second tibia (Tibia A) have never been described.

The salient points in Oppenoorth's first description³ can be summarized as follows:

Skull I is an almost complete calvarium broken off over the middle of the orbits. It is said to be that of a fairly old female, as indicated by the sutures which are fused to a great extent. Its cranial capacity is *ca.* 1200 cc.

Skull II is the frontal bone of a child between three and seven years of age.

Skull III is a defective calvarium of an individual of advanced age, consisting of a piece of the frontal bone, the two united parietals, and a part of the occipital bone.

Skull IV is the anterior part of a calotte extending from below the glabella to the mastoid suture. This individual, probably female, was middle aged.

¹ Black, 1931, 104.

² Boule, 1937.

³ Oppenoorth, 1932c, 272.

Skull V is a calvarium of extraordinary length: greatest length 221 mm. It is less complete than Skull I; the base from nasion to halfway up the nuchal plane is broken away. It is that of a male individual whose age is not estimable. Its cranial capacity is *ca.* 1300 cc.

Skull VI is an almost complete calvarium. Although the base is preserved, no details are given. It is that of an adult and, as are Skulls I and IV, which it resembles in form and size, is probably an adult female. The cranial capacity is 1175 cc.

Oppenoorth's second statements (1937) concerning the skull of Solo man are chiefly based on Skulls I, V, and VI, but the latter two were apparently not studied so thoroughly as Skull I. Oppenoorth probably wrote this paper intending to prove that Solo man is not a Neanderthalian form, as he had suggested in his earlier publications, but a fossil *Homo sapiens* form (see p. 223). The following is based on Oppenoorth's summary of the characteristic features of the Solo skulls found by him:

The flat forehead is combined with a heavy torus supraorbitalis, a considerable postorbital constriction, and a vertically compressed occiput with a torus occipitalis transversus. The heavy bar of bone above the orbits is not separated by a slight depression, as in Neander-

thal man, but is "more chimpanzoid" with a nearly straight, continuous ridge; only Skull VI has a slight depression, so that the torus appears to be arc-shaped above the orbits, while the upper side forms a straight line. Although the orbits are broken away immediately beneath the torus, it seems impossible that they were round as in the Neanderthal type—they must have been more rectangular, as in Cro-Magnon man. A fossa supraglabellaris is absent in the Ngandong skulls; the torus supraorbitalis passes away imperceptibly in the frontal bone with a fluent, barely curved line. The frontal bone has a slight crest lacking in Neanderthal skulls and gives the Ngandong skulls a slight gable-roof form to some degree.

Oppenoorth emphasized that most of these features are lacking in Neanderthal man, but omitted to mention that they are characteristic of *Pithecanthropus* and *Sinanthropus*. Nevertheless, he ranks Solo man with fossil "*Homo sapiens*" and not with these hominids.

[In general form] the occiput of the Neanderthal skulls can be compared with the form of an egg with a ridge, the torus occipitalis transversus, but on the Ngandong skulls it has quite another shape. The nuchal plane is very flat, has a strong crest and is nearly rectangular (about 100°) to the upper squama. Between the two parts of the occiput is a heavy torus and so the occiput has a striking resemblance to that of Rhodesian man.

But Oppenoorth, apparently becoming aware that statements like this may affect his revocation of the Neanderthal characteristics in the Ngandong skulls, further remarks:

I hope to have shown above that those neanderthaloid characteristics are more seeming than real as far as proof of the identity with Neanderthal man is concerned.¹

He makes additional contradictory statements:

As in recent man the maximum breadth of the Neanderthal skull is rather high on the skull; on the Ngandong skulls it lies lower and a little above that of *Sinanthropus*, a more primitive feature.

The temporal bone has a strong disparity compared to that of Neanderthal man. Here the mandibular joint shows distinctly simian traits; the glenoid cavity is so shallow that its deepest parts lie level with, or below the midpoint of the ear passage and an

articular eminence is only just visible. On the Ngandong skulls, however, the articular fossa is deep and reaches up almost to the level of the roof of the ear passage; in front of it is a well marked articular eminence. . . . This is a typical modern human form of the joint. The tympanic plate in Neanderthal man is also simian; that of *H. soloensis* is much bigger with a sharp crest that divides it into two parts, an anterior with a convex and a posterior with a concave surface.

The direction of the long axis of the elliptical porus acusticus externus is neither forward as in Neanderthal man, nor backward as in Neolithic and modern man, but about vertical. The processus mastoideus of Neanderthal man is small and has a simian trait; that of *H. soloensis* is a real pyramidal process, quite as in modern skulls. . . . The length of the mastoid process in *H. soloensis* skull is thus far above the limit of Neanderthal length.²

These statements with regard to the temporal bone of Solo man will be discussed later. But to claim that the features of this bone are "simian," more "primitive" in the Neanderthals, and more like modern man in Solo man shows only that Oppenoorth was not familiar with the anatomical facts. The same is true of his statement that

The foramen magnum [in the Ngandong skull] lies more forward [than in Neanderthal man] and so the head is better balanced.³

The two tibiae of Solo man are not mentioned in Oppenoorth's first publications. Only in the later one (1937) he stated:

The only limb bones found are a fragment [?] of a tibia and a damaged [?] right one and this tibia [which one?] shows no affinity with Neanderthal man and thus corroborates the conception that the two forms are different.⁴

The length of the tibia is given as 365 mm. Oppenoorth stated furthermore:

A peculiar feature is the absence of the sharp crest, the crista anterior; in its place is a small rounded anterior surface.⁵

These remarks make me doubt that Oppenoorth ever saw the tibiae he describes because both tibiae have a well-developed anterior crest. Besides, the one described by Oppenoorth (obvi-

² Oppenoorth, 1937, 355-356.

✓ ³ Oppenoorth, 1937, 356.

⁴ Oppenoorth, 1937, 351.

⁵ Oppenoorth, 1937, 357.

¹ Oppenoorth, 1937, 352.

ously B) is not a fragment, but almost complete, with only the proximal epiphyseal portion broken off in part. The second tibia consists of a shaft slightly damaged, with the upper and lower ends missing. In addition, this tibia (A) is much more robust than Tibia B and does not differ essentially from known Neanderthal tibiae as far as robustness is concerned.

As will be demonstrated below, Oppenoorth's statements on the morphology of the skeletons of Solo man are in part correct, in part quite incorrect. It is difficult to judge whether inaccuracy is due to inadequate preparation of the originals or to Dubois' suggestion that Solo man is not a primitive human type but a "*Homo sapiens*." One thing seems to be certain: when Oppenoorth published his papers, he did not have all the material. Even that available to him had not been studied with the care and anatomical knowledge it required. Therefore, Oppenoorth's conclusions as to the general character of Solo man and his classification have no scientific basis.

As far as I know, no study based on the originals of Solo man has been published by anyone else. Wherever Solo man and his morphological character were discussed, the authors referred to Dubois or Oppenoorth as their sources. In 1947 Wanda Steślicka, who had access to the inaccurate casts of the skulls and

skull fragments, attempted to make an analysis of these skulls. This analysis, based on the traditional measurements and ignoring all non-metrical characters, led her to conclude that Solo man is in principle a Neanderthal form. I got off very badly in her paper. Although she was apparently not informed of my studies, she states that I first regarded Solo man as a Neanderthalian, but had later changed my mind in accepting Oppenoorth's second conception (1937) according to which Solo man belongs, as she reports, to the "genus *Pithecanthropus*" and not to "genus *Homo*." It is obvious that Steślicka, on the one hand, completely misunderstood Oppenoorth, who held the opposite opinion, and, on the other, she was not acquainted with my work on *Sinanthropus*. Strangely enough, *Sinanthropus* was not the subject of her comparison. Therefore it escaped her that out of 58 special characters of the calvarium, Solo man has 55 to 56 in common with *Sinanthropus* and *Pithecanthropus* and only two or three with Neanderthal man. It is true that the height of the Solo skulls, the height-length index, and the different angles of the frontal bone fall into the range of the Neanderthalian as she claimed. But these and other measurable features do not justify ranging Solo man as a hominid form with the latter group, as will be shown below.

NOMENCLATURE

As noted in the two preceding sections, Oppenoorth at first (1932) intended to describe the Ngandong finds under the name "*Javanthropus soloensis*." However, he almost immediately changed this designation to "*Homo soloensis*." The motive for this substitution is revealed in his later paper (1937). Oppenoorth was convinced that he was dealing with a Neanderthal type of man, but one generically different from the known European type and in some respects a type closer to the African Rhodesian man. Therefore, he wanted to distinguish the Ngandong human form from both these types by assigning a special name to it, namely, *Javanthropus*. From the beginning Dubois, however, apparently protested against such a classification.¹ He considered the Ngan-

dong man, like the Wadjak man, a fossil form of *Homo sapiens*. Oppenoorth adopted this view without any reservations. He abandoned the first name, *Javanthropus*, and recognized "*Homo soloensis*" as the only correct and adequate designation.

I do not intend to discuss the justification for assigning and changing names, especially in a situation like that under consideration, in which a name was given and revised, although both authors had only a very vague idea of the morphological character of the specimens involved. Neither one studied the complete series and all the well-preserved specimens. As to nomenclature, in general, I believe that all the hominids now known belong morphologically to a single species, and therefore I regard subdivisions expressed in terms of fixed taxonomy as a matter of secondary concern. In the present

¹ Cf. Dubois, 1932.

state of our knowledge, the first and essential objective is for a precise description of all the morphological characters to enable us to assign a given hominid specimen to a place in the phylogenetic morphologic sequence, and not begin with a name which fits the taxonomic rules and is then forever irrevocable even if it turns out subsequently that the name was incorrectly conceived.

Earlier studies¹ led me to the conviction that Ngandong man is not a true Neanderthal type but distinctly more primitive and very close to *Pithecanthropus* and *Sinanthropus*. For this

reason I ranked Solo man with the same group of early hominids as the two latter forms and called the whole group Archanthropines. The subsequent discussion will prove this general classification to be correct. Considered from this point of view, it is entirely irrelevant whether Solo man is called "*Javanthropus soloensis*" or "*Homo soloensis*." I decided to use simply "Solo man." It would certainly increase the confusion if I were to call him *Pithecanthropus soloensis* because of his morphological affinity to *Pithecanthropus erectus*, *P. robustus*, or *Pithecanthropus (Sinanthropus) pekinensis*.

THE MATERIAL

The Solo man material brought to the American Museum of Natural History by Dr. von Koenigswald, when he arrived from Java in September, 1946, consisted of calvaria and calvarial fragments totalling 10 individual pieces. They were designated as Skulls I, II, III, IV, V, VI, VII, VIII, X, XI. Skull IX of the original series was missing. During the war it had been confiscated and sent to Japan as a gift to the Emperor. Following the Japanese surrender, Lieut. Walter A. Fairservis, Jr., Army of the United States, made a search for it at the request of Dr. H. L. Shapiro and found it in the Imperial Household Museum in Kyoto. Upon the request of the Netherlands Military Mission in Tokyo, the skull was placed in the custody of Lieut. Fairservis, who delivered it to Dr. von Koenigswald in New York, December 1, 1946. The skull was undamaged despite these adventures. In addition to the calvaria, there were also two right tibiae; one was almost complete, the other consisted of the shaft, broken into two pieces, which, however, fitted together without any gap; it could easily be restored.

The skulls had been freed from the matrix and restored in part by Oppenoorth. However, the preparation and restoration were somewhat inadequate, and it was necessary to remove fragments of matrix still adhering to them. In those skulls in which the restoration was obviously inaccurate, the parts originally broken were disassembled and after removal of the

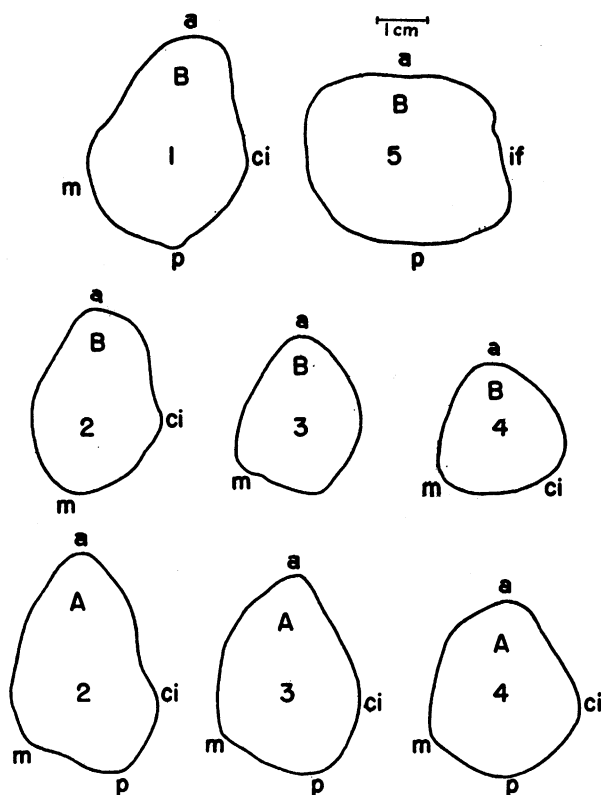


FIG. 3. Transverse sections through Tibia A (third row) and Tibia B (first and second rows). 1. At the level of the tuberositas tibiae. 2. At the level of the foramen nutricium. 3. At the level of the middle of the tibia. 4. At the level of the least circumference. 5. Above the articulatio tibio-fibulario. Abbreviations: a, anterior; ci, crista interossea; if, incisura fibularis; m, medial; p, posterior.

¹ Weidenreich, 1943, 204-205, 212, 230-232, 237; 1946, 39, 40.

matrix adjusted more accurately. The detailed features of the bases of Skulls VI and XI that were badly obscured by the matrix were cleaned with special care. In both skulls the matrix which still filled the cranial cavity was soaked with shellac to harden and preserve the bone. In Skull XI the rest of the cavity was filled with plaster in which a metal rod was embedded through the foramen magnum. Since the cranial cavity was accessible in this skull only through the occipital foramen, its cleaning was not an easy job.

For all these reasons the casts of the skulls made in Bandung can be used for comparison with the drawings and photographs or measurements presented in this paper only with reservations. In some skulls the deviations may be negligible; in others, they are considerable.

All the cranial bones, except for Skull II, apparently a child, and Skull IV, an adolescent, are extraordinarily thick and heavy; all are highly mineralized. The color varies from a light gray and yellow-brown to dark red-brown. The state of preservation varies considerably. Skulls VI and XI are well preserved, and even those parts of the base that are so very fragile in modern man are intact. Skull X is badly weathered and eroded. Skull I appears polished, whether as the result of rubbing during the removal of the adhering matrix or from wear by the sand in which the calvarium was embedded cannot now be determined. A dark brown spot extends over a large area of the cranial surface of Skull V. Skull VI has several similar small dark brown areas. They may have been caused by precipitation of manganese, but why only in these places and on these skulls the spots occur is difficult to explain.

SKULL I

Plates 18a-d, 19a-b; Figures 6, 13

Skull I is a calvarium. The greater part of the base (Pl. 18b), from the fronto-nasal suture to a transversal that crosses the base at the level of the two processus mastoidei, is missing. The left lateral cranial wall below the temporal line is likewise missing (Pl. 19b). The entire left corner of the supraorbital torus and the adjoining squamosal part of the frontal bone is broken off (Pl. 18b). In addition the calvarium is some-

what twisted. The right temporal bone and the right half of the nuchal plane of the occipital bone are depressed inward, and the corresponding parts of the left side, as far as they are preserved, bulge outward (Pl. 18b). It was impossible to correct this distortion. The warping must have occurred when the bone was still plastic. Observed from behind, the skull is, therefore, asymmetrical—the right side somewhat depressed and the left side slightly bulging (Pl. 18d).

The base (Pl. 18b) differs considerably from Oppenoorth's illustration.¹ From his description it is obvious that the base had not been prepared, and a large part of the cavity was still filled with matrix. In Oppenoorth's illustration the contours of the foramen magnum seem to be intact; actually only the posterior parts of its margins are preserved. Furthermore, Oppenoorth stated that the right condyle is preserved. However, he apparently mistook the swelling that I have called *tuberositas post-condyloidea* (p. 264) for the occipital condyle. A similar structure, also well developed, is visible on the left side, but the base of both condyles, as well as their articular facets, is missing. I do not know whether or not some of the missing parts of the base were originally embedded in the matrix and later lost when the skull was finally prepared.

The main sutures are completely fused. A short section of the sagittal suture is still recognizable at the vertex; although more obscured, it is possible to trace the suture on the left side for the greater extent of its length. The lambdoid suture is more clearly discernible, especially in its *pars media* and *asterica*, as is true of the squamosal suture (right side). But forward from the porion transversal the cranial wall is apparently broken along this suture. The occipito-mastoid suture is visible near the asterion and behind the mastoid process.

The superstructures and all the muscular crests and tuberosities, particularly those of the nuchal squama, are well developed and the thickness of all the bones is considerable, but these details are obviously less pronounced than in other skulls of the Ngandong series. This suggests that the skull may be that of a female and, if the state of the closure of the sutures in

¹ Oppenoorth, 1932a, Pl. 3.

modern man can be used as a criterion, the skull is that of an individual of advanced age.

SKULL II

Plate 19c-f

Skull II is represented only by the frontal bone which is complete, except for the lower right part of the squama and the entire right

the other skulls. The supraorbitals are barely developed. The relatively small size of the frontal bone and the under-development of the supraorbitals alone do not prove that Skull II is that of a Solo child, three to five years of age, as Oppenoorth¹ suggested. It even matches the frontal bones of modern adult individuals, especially females, in its least and greatest frontal breadth, in mid-sagittal length (nasion-bregma

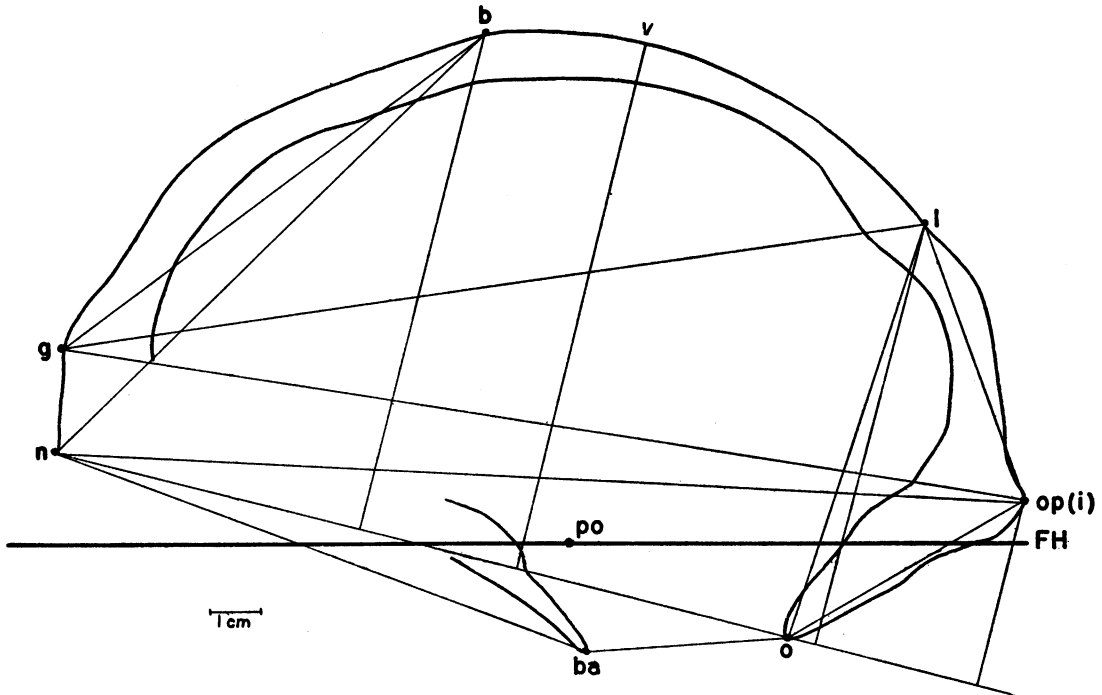


FIG. 4. Mid-sagittal craniogram of Solo Skull VI, outer and inner contours of the braincase. The straight lines connecting the landmarks indicate the measurements listed in Table 6. *Abbreviations:* b, bregma; ba, basion; FH, Frankfort Horizontal; g, glabella; i, inion; op, opisthocranium; po, porion; v, vertex.

orbital portion. The bone is broken off along the coronal suture which is preserved for its entire length on both sides. The glabellar and the nasal part is preserved, but damaged. The outer and inner surfaces are cracked and slightly weathered.

The greatest breadth (stephanion) of the frontal bone is 110 mm., while the nasion-bregma chord is 115 mm. The former measurement is 3 to 5 mm. less than that of the smaller adult skulls of the same series, while the latter is equal to it, but the thickness of the glabellar region (11.5 mm.) is only half that of

chord), and in thickness. Other structures, however, emphasize the infantile character of the bone. On the other hand, no other bones found at the same site can be claimed to be those of modern man. Therefore, we must conclude that the frontal bone is that of a Solo child, although it may be older than estimated by Oppenoorth. I shall return to this question below (p. 250).

The bone is fossilized to the same degree as the other skulls and has the same sepia brown color.

¹ Oppenoorth, 1932a.

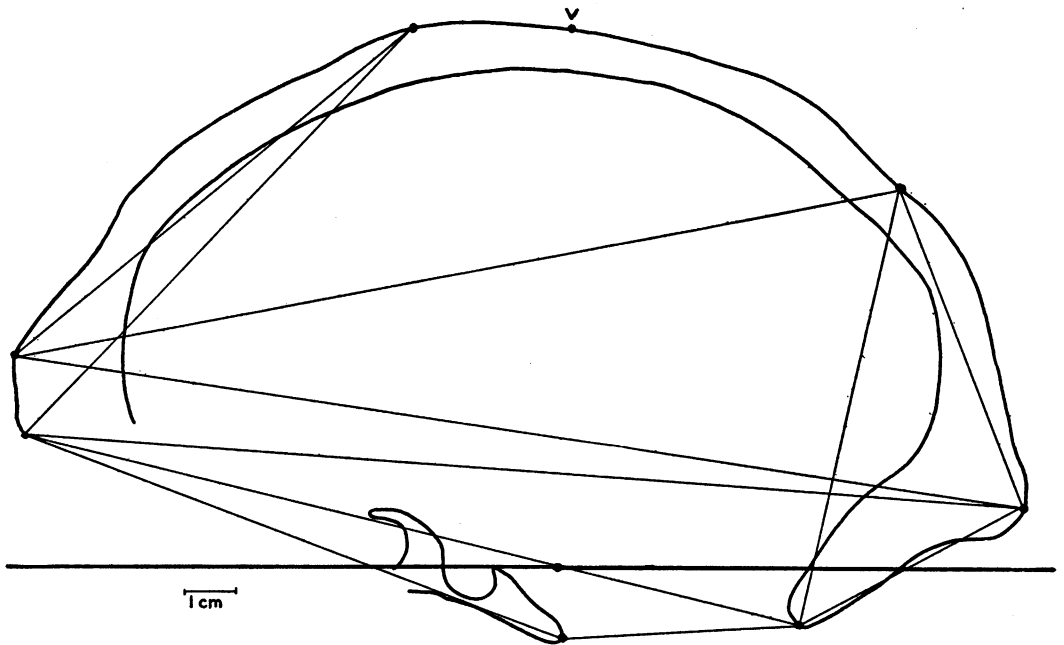


FIG. 5. Mid-sagittal craniogram of Solo Skull XI; outer and inner contours of the braincase. For explanation of landmarks and connecting lines, see Fig. 4.

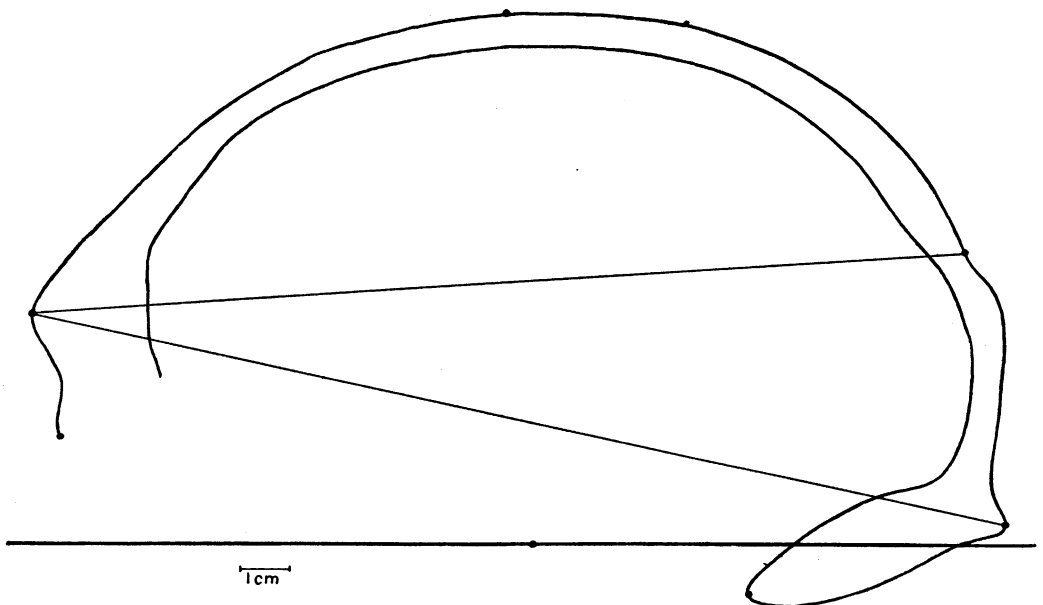


FIG. 6. Mid-sagittal craniogram of Solo Skull I; outer and inner contours of the braincase. For explanation of landmarks and connecting lines, see Fig. 4.

SKULL III

Plate 20a-c

Skull III is a fragment of a calotte which consists mainly of the two parietal bones, the posterior part of the squama of the frontal bone, the anterior parts of the occipital bone (chiefly of the occipital squama), and the mastoid portion of the left temporal bone. All these individual bones are united, the sutures between them being completely closed. The coronal suture is not recognizable, but the sagittal suture is still visible along the vertex as is the lambdoid suture for its total length. The break-ages occur approximately along the squamosal, parieto-mastoid, and occipito-mastoid sutures.

All the bones are very thick. This fragment certainly represents one of the heaviest skulls of the whole series. Although the supramastoid and mastoid crests are very pronounced, the occipital torus is less developed than in other skulls. The skull was apparently that of a male individual of advanced age.

The fossilization is very complete. There are no indications of weathering or erosion. The color, in general, is brown, lighter and darker brown spots alternating.

A small piece of bone of considerable thickness and of the same color as that of the main piece was attached to the right side. It is certainly a fragment of a parietal bone (Pl. 20d). It is bevelled along one margin, suggesting that it is the section of the parietal bone that forms part of the squamosal suture. At the cerebral surface of the fragment (Pl. 20e), there are deep furrows, apparently for the ramification of the anterior meningeal vessels which radiate from the larger vessel. The course of the squamosal suture, as well as the ramification of the anterior meningeal vessels, indicates that the piece of bone is a fragment of a right parietal bone near its sphenoid angle. Since there was no well-defined contact with the main piece, I decided not to attach it.

SKULL IV

Plates 20f, 21; Figure 10

Skull IV is a calotte consisting of the frontal bone and the two parietals. The supraorbital region between the fronto-zygomatrical sutures is preserved in its total length, as is a small part

of the adjoining orbital roof on both sides. All other cranial bones are missing, having been broken off along their sutures (spheno-frontal, squamosal, occipito-mastoidea, and lambdoid). All these sutures are so perfectly preserved that there can be little doubt that they were still wide open when the skull fell to pieces. The coronal and sagittal sutures are recognizable in their entirety, but they have already begun to fuse.

The calotte is relatively small and its bones are thinner than those of any of the other skulls, except Skull II. The supraorbitals are also much less developed than in the other specimens. All this indicates that the skull must have been that of an adolescent individual, possibly a female.

Both the degree of mineralization and the color of this calotte are the same as in the other specimens. The calotte is remarkable because the outer surface of almost the entire right parietal bone is occupied by a large lesion with regular islands of newly formed bone substance (p. 238).

SKULL V

Plates 22, 23a-b, 44e; Figures 7, 14

Skull V is a calvarium. Its base is broken out except for the greater part of the nuchal squama of the occipital bone, the lateral part of the left temporal bone, and the anterior part of the orbital areas of the frontal bone. Otherwise it is almost complete. The right side, from the temporal line down, is pressed inward and is broken in part; the corner of the right supraorbitals and the adjoining part of the frontal bone is broken off. All this produced a slight asymmetry of the calvarium.

The skull is the longest of the entire Solo series (greatest length 221 mm.), and the cranial bones are the thickest and heaviest. All the sutures are closed, but their outer lines are still discernible: the lambdoid and squamosal sutures in their total extent, the sagittal suture in part, while the coronal suture is more obscured, especially on the left side. Distinct traces of a transverse occipital suture cross the squama along the sulcus supratralis, indicating that the entire occipital squama has represented a large os interparietale ("os Incae").

Its size and massiveness indicate that it is the skull of a male; the condition of the sutures,

when compared with that of the other skulls in the series, suggests one of middle age.

The skull is heavily fossilized. It weighs 2 pounds $8\frac{1}{2}$ ounces (1139 grams). It is sepia brown, and a broad stripe of dark red-brown extends diagonally over the whole surface from the frontal bone on the right side to the nuchal plane of the occipital bone on the left side. The skull is slightly weathered and on the left side rather than on the depressed right side bears

(in addition to Skull XI) is the best preserved base of any fossil hominid ever found. No artificial asymmetry is recognized. The entire facial skeleton is broken away below the supraorbital margins and the fronto-nasal suture. Although all the cranial sutures are fused, they are readily recognizable throughout their total extent; only the obelion sections of the sagittal suture and the right leg of the lambdoid suture are somewhat obscured. Despite the general heaviness of

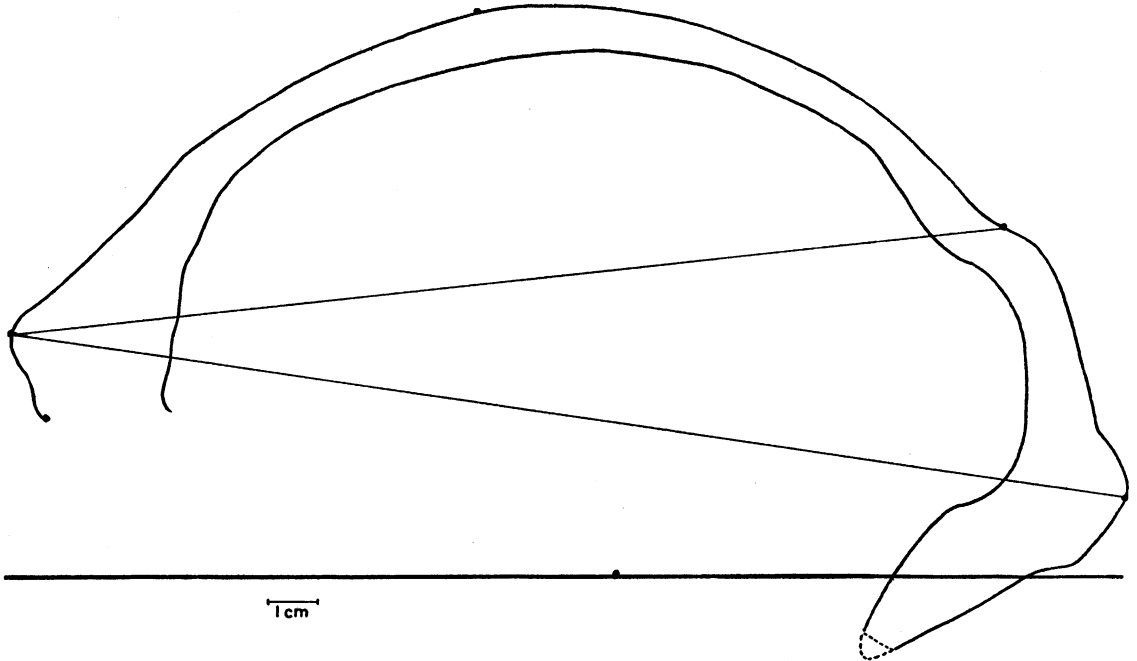


FIG. 7. Mid-sagittal craniogram of Solo Skull V; outer and inner contours of the braincase. For explanation of landmarks and connecting lines, see Fig. 4.

some evidence of erosion, especially around its basilar parts.

SKULL VI

Plates 23c-d, 24, 38, 42, 44d, 47a;
Figures 4, 11

Skull VI is an almost complete calvarium. The entire base is preserved, including the greater part of the pterygoid processes of both sides, the roof of the orbits, and the ethmoidal bone between. The left corner of the supraorbitals and the zygomatic processes of both temporal bones, including their roots, are broken off. The right occipital condyle is only partially preserved, but was easily restored to match the completely intact left occipital condyle. This

the skull, the muscular relief is less pronounced than in other skulls of the series. The mastoid process, completely preserved on both sides, is relatively small.

The skull as a whole is one of the smallest of the series. All this indicates that it is that of a female, and probably a relatively young adult. The skull is heavily mineralized, weighs 2 pounds $3\frac{1}{2}$ ounces (988 grams), and is not weathered. But there are small and large injuries all over the top; a very large one, almost circular, with a diameter of 50 mm., is located on the left parietal bone just behind the vertex. I shall return to these peculiarities later. The color of the skull is light brown, but large reddish brown spots are distributed over the whole specimen.

SKULL VII

Plate 25a-b

Skull VII is represented by only a small fragment of a right parietal bone consisting of the entire angulus mastoideus, bordered by the mastoid portion of the lambdoid suture, the parieto-mastoid suture, and the posterior portion of the squamosal suture. By a strange coincidence, the fragment corresponds almost exactly to Skull VII of *Sinanthropus pekinensis*, also represented only by the mastoid angle of the right parietal bone. As in the *Sinanthropus* parietal, the fragment undoubtedly belongs to a young individual, since all three bordering sutures are open and well preserved in all details. The fragment is only about two thirds as thick as the other cranial bones in the same region (torus angularis) of the Solo series, indicating that the individual was not only young, but possibly a female.

The fossilization is similar to that of the other skulls in the series and is of the same sepia brown. The outer surface is very slightly weathered.

SKULL VIII

Plate 25c-f

Skull VIII is represented by the two parietal bones which were found separately, but it was possible to unite them in the sagittal suture without difficulty. The two bones are preserved in their entirety; the coronal, lambdoid, and the right and left squamosal sutures form the borders of the calvarial fragment. None of the sutures bear any evidence of previous fusion; their denticulations, which resemble crests, as in *Sinanthropus*, and not points, as in modern man, are sharply cut. This indicates that the skull fell asunder along the sutures, but no other bones or their fragments were recovered. The two parietal bones are very heavy and of extraordinary thickness, especially in the torus angularis region. They may, therefore, have belonged to a male, but the condition of the sutures indicates a relatively young individual.

The fragments are heavily fossilized and are light brown. The outer surface is cracked, especially the area of the parietal tuberosity on the right side. The entire surface is also somewhat weathered, but this is much less pronounced on the cerebral side which is also lighter in color.

SKULL IX

Plates 26, 27a; Figures 8, 15

Skull IX is a calvarium with the greater part of its base missing. The lateral portion of the right temporal bone, the region of the articular tubercle of the left temporal bone, and the posterior half of the nuchal plane are preserved.

The greater part of the roof and the lateral walls of the calvarium are preserved, but they were badly smashed and it was possible to unite them only by filling the entire posterior half of the calvarium with plaster. Nevertheless, some of the fragments, both small and large, remained dislocated. This dislocation, however, does not influence the general form of the calvarium; the skull has been left as it is.

The sutures are fused. The sagittal suture is recognizable only at the vertex and the lambdoid suture near the anterior region. As the temporal squamae of both sides are shattered, it is difficult to describe the condition of the squamosal sutures. The occipito-mastoid sutures are still discernible. Although the skull is one of the smaller specimens in the series, the muscular relief of the occipital and temporal bones is surprisingly strong and more pronounced than in the larger and otherwise heavier specimens. The condition of the sutures indicates that the calvarium is that of an adult of advanced age; its size suggests a female, although its heaviness is a male characteristic.

The skull exhibits the same degree of fossilization as the other specimens of the series. There is scarcely a mark of weathering or erosion. The ground color is sepia brown, but almost the entire top of the calvarium seems black. No attempt to restore or remove the plaster from inside the calvarium was made because all the fragments would have been dislocated.

SKULL X

Plates 27b-d, 28a-c; Figures 9, 17

The greater part of the base of Skull X is missing from behind the supraorbitals to the opisthion. However, the lateral portion of the base of both temporal bones is preserved, as is the major part of the nuchal plane, especially that of the left side. Although the calvarium was shattered, an almost complete reconstruction was possible.

Although the specimen is badly weathered and eroded, the most characteristic features of

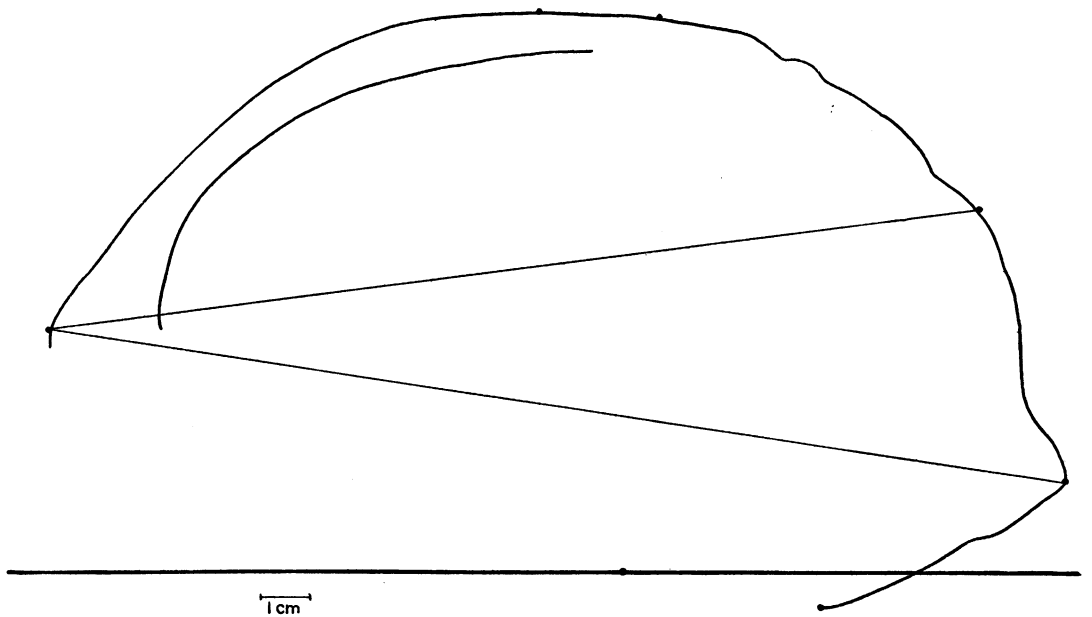


FIG. 8. Mid-sagittal craniogram of Solo Skull IX; outer and part of the inner contour of the braincase. For explanation of landmarks and connecting lines, see Fig. 4.

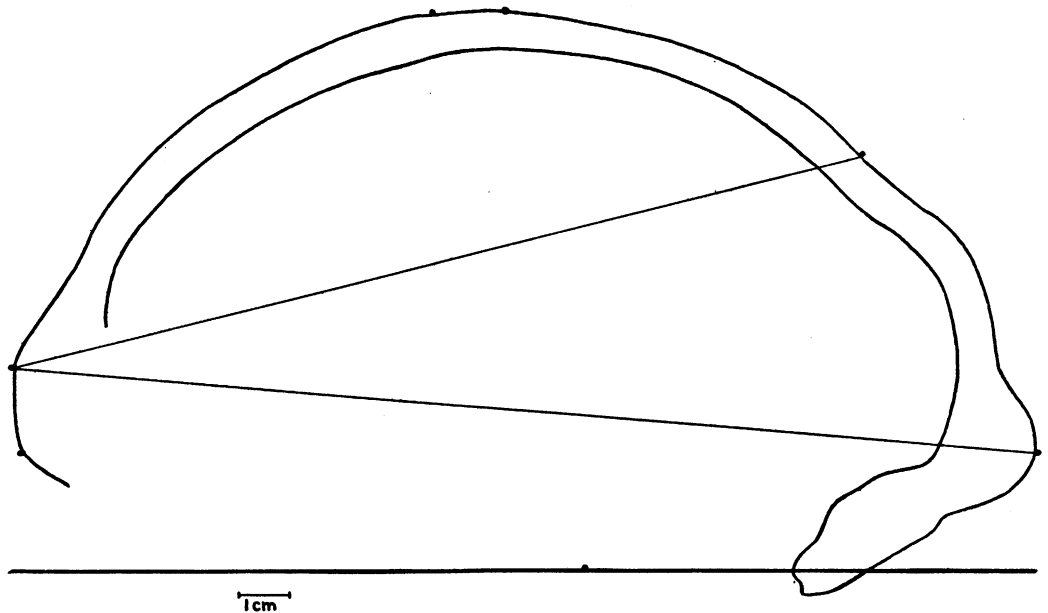


FIG. 9. Mid-sagittal craniogram of Solo Skull X; outer and inner contours of the braincase. For explanation of landmarks and connecting lines, see Fig. 4.

the Solo series are readily recognizable. The sagittal suture from the bregma to the obelion region is very clear. Except for small sections of the lambdoid suture on both sides, all the other sutures are completely obscured. In size and development of the muscular relief of the occiput, Skull X closely resembles Skull IX. The individual may have been a female of advanced age, with some masculine characteristics.

All the sutures are fused, though still recognizable, along their entire length. The synchondrosis speno-basilaris is indicated by a narrow transverse groove. Superstructures and muscular relief are well developed. The thickness of the cranial walls is very pronounced, imparting a masculine aspect to the skull although it is much smaller than Skull V. The skull is certainly that of an adult, but one less

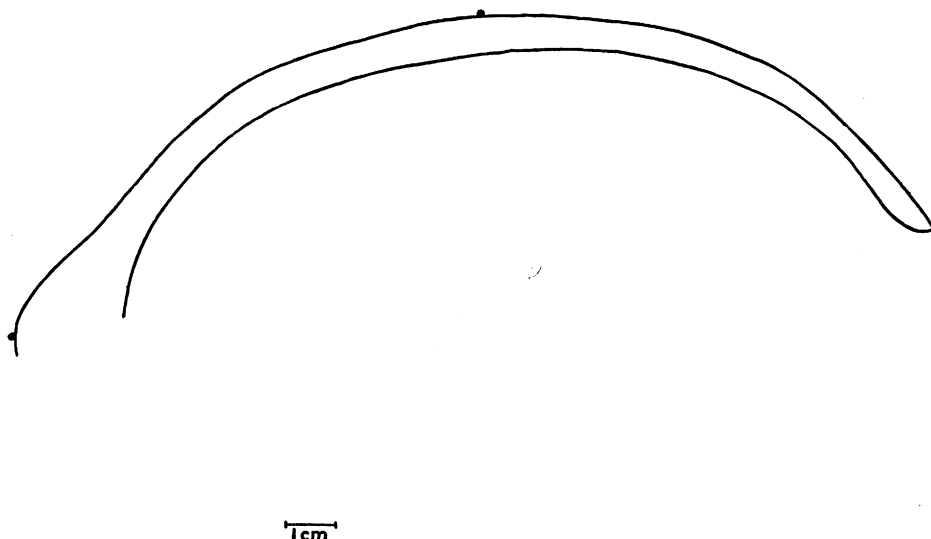


FIG. 10. Mid-sagittal craniogram of Solo Skull IV; outer and inner contours of the fragment of the calotte. For explanation of landmarks, see Fig. 4.

The fossilization is identical to that in the other specimens of the series. The color is gray-brown.

SKULL XI

Plates 28d, 29, 30, 33-37, 39, 43, 44a, 45, 46, 47b;
Figures 5, 12, 17, 21, 22c, 23b

Skull XI is an almost complete calvarium. The base is preserved, except for the anterior, which has a large hole extending from the posterior wall of the frontal sinuses to the occipito-sphenoid. All other structures of the base are in excellent condition except for those projecting markedly: the pterygoid process, the condyles, and the apex of the mastoid process, which are broken or worn off. The top and the lateral walls of the calvarium are almost completely preserved. Only the right parietal bone is slightly depressed along its temporal line.

advanced in age than other specimens with their sutures fused.

The skull is highly mineralized. The calvarium weighs 2 pounds 9 ounces (1153 grams) and is the heaviest skull of the entire series. This may result from the greater thickness of the bones or their higher degree of mineralization. The color is light brown. On the right side of the top of the calvarium, especially along the temporal line, are signs of erosion.

TIBIA A

Plate 31a-d

Tibia A is represented only by a large fragment of the shaft; the proximal and distal ends are broken off. The part preserved is, in general, in very good condition; only some parts of the anterior crest and a section of the interossea

crest are rubbed or worn away, but these were easily restorable. The tibia is that of an adult, probably a male, and much heavier and larger than Tibia B.

The bone, gray-brown, is highly mineralized; the weathering minimal.

TIBIA B

Plates 31e-f, 32

Tibia B is an almost complete right tibia. The shaft is intact for its total length. Except for the surface of the bone, which is worn off around the

distal epiphysis, including the fibular incisure, the distal extremity with the medial malleolus and the articular facet is also preserved. The proximal extremity is broken away just above the upper end of the tuberositas tibiae; only a small portion of the medial side, a small area of the articular facet of the medial condyle, remains. The shaft is slightly weathered, especially on its posterior and lateral surfaces.

The bone, that of an adult, probably a female, is as a whole slender and fossilized to the same degree as the skulls. It is dark brown along the medial surface, lighter brown in other areas.

SEX AND INDIVIDUAL AGE

Although the 11 skulls and skull fragments undoubtedly belong to the same hominid type, they reveal great differences in size, heaviness, and the condition of their sutures. These distinguishing features can be used as criteria for the determination of individual age and sex.

Determination of the age is very simple in Skulls I (Pl. 19a-b), IV (Pls. 20f, 21), VII (Pl. 25a-b), and VIII (Pl. 25c-f), which are all represented by fragments that demonstrate that the skulls broke apart along their sutures. It can be concluded, therefore, that the individuals must have died at an age when the sutures had not yet begun to fuse. Skull II is the lowest on the age range of the series. The size of the fragment indicates that it is part of the skull of a child, but, as no teeth are preserved, it is impossible to determine the exact age with any degree of accuracy. Estimating on the basis of the thickness of the bones permits us to place Skull VII next in age. Employing the same criteria, the sequence is completed by Skull IV, followed by Skull VIII. When compared with the child's Skull II and the remainder of the series, which consists of adult skulls, Skulls VII, IV, and VIII can be classified as adolescents. The fusion of the sutures is the single feature common to these adult skulls (I, III, V, VI, IX, X, and XI), though the degree of fusion is not identical. The sutures in Skulls V and VI are recognizable to a greater or lesser degree, but in Skulls I, III, IX, and X they are almost completely obscured.

To summarize: The skulls can be classified into two age groups, the first comprising one

very young individual (Skull II) and three adolescents (Skulls VII, IV, and VIII), and the second, two young adults (Skulls V and VI) and four of more advanced age (Skulls I, III, IX, and X).

This estimate of age is based on the assumption that the cranial sutures in early human types close at the same age as they do in modern man. However, I have shown in two earlier papers¹ the condition of the sutures of *Pithecanthropus* and *Sinanthropus* suggests that they close much earlier in early hominids than in modern man. In this regard early hominids resemble living anthropoids whose cranial sutures are already fused when permanent dentition is completed. We cannot resort to the dentition as a criterion of age of these Solo man calvaria because the jaws and teeth are missing. Nevertheless, the fact that in six out of 11 individuals in one population the sutures are completely fused is entirely contrary to the situation in modern man. The percentage of coalescence of the sutures to such an extent as occurs among Solo man (54.5 per cent) will never be found among modern men. Complete closure of all cranial sutures is very rare in modern man, although such complete fusion should presumably occur more rather than less frequently in modern man because his cranial bones average one half or even one third the thickness of the Solo skulls.

Sex differences of the Solo individuals can be inferred only from the size and massiveness of the calvaria and their heavy superstructures and muscular crests. On the basis of these cri-

¹ Weidenreich, 1941, 1943.

teria, Skull V, the largest and one of the heaviest skulls in the series, is classified as a male. Skull and skull fragments XI, III, and VIII approach Skull V in massiveness and heaviness, but they are smaller. If these are also males, we would have two types, a small

Australian "natives." Therefore, Solo man, regardless of sex, is a very heavily built hominid, much heavier than *Sinanthropus* whose sexually derived differences seem to be much more pronounced; even the male individuals of Peking man are much less heavy than

TABLE 3
GENERAL PECULIARITIES OF THE SOLO SKULLS BEARING ON SEX AND AGE

Solo Skulls	Sutures	Superstructures	Thickness	Age	Sex	Injuries
I	Completely closed, but some still recognizable	Well developed, but less so than in other specimens	Moderate	Adult, advanced age	F	5: 1 square, 4 short, more linear; none of them penetrating
II	Completely open	Not developed	Relatively thin (not developed)	Child	F?	None
III	Completely closed, but some recognizable	Very pronounced	Very heavy	Adult, advanced age	M	None
IV	Completely open	Very weak	Relatively very thin	Adolescent	F?	Large injury
V	Completely fused, some less	Very pronounced	Very pronounced	Adult, relatively young	M	None
VI	Closed, but recognizable	Less pronounced than in other specimens	Relatively thin	Relatively young	F	Large injury; several smaller ones; 1 at nuchal planum
VII	Completely open	Medium	Relatively thin	Adolescent	F	None
VIII	Completely open	Medium	Heavier than VI	Adolescent	M?	Cracks on both parietal tuberosities
IX	Completely closed	Very pronounced	Moderate	Adult, advanced age	F?	None
X	Fused, but partly recognizable	Well developed	Moderate	Adult, advanced age	F?	1 weathered
XI	Fused, but all well recognizable	Well developed	Very pronounced	Adult, but young	M?	None

and a large type. In comparison with these male individuals, Skulls I, VI, IX, and X would therefore represent females. If this classification is correct, these females would have "masculine" traits, differing slightly from at least the smaller males in the development of their superstructures and muscular crests. This may occur also in modern man, for example, among

the female individuals of Solo man.

The contrast between the two tibiae is similar. Tibia B is powerful, but slender; the circumference at the middle of the diaphysis is 86 mm. Tibia A is robust and heavy, its circumference 101 mm. at the same level. Therefore, Tibia B probably belonged to a female, and Tibia A to a male.

INJURIES

Most of the Ngandong skulls were found more or less broken. The entire facial skeleton was missing in all the skulls. Of Skulls II, III, IV, VII, and VIII only fragments were found; the braincases of Skulls VI and XI were almost complete; Skulls I, V, and X were broken, but the greater part of the fragments were recovered and restored; Skull IX seems to have been complete but was shattered when excavated.

In addition to injuries that may have resulted either from earth pressure or accidentally at the time of excavation, others were apparently inflicted during the life of the individuals or possibly immediately after death while the bones were still covered with the soft parts. In some instances it is impossible even to hazard a guess as to the time or cause of the wound.

Skull I (Pls. 18, 19a) has a square injury at the tuberosity parietalis of the right side near the temporal line; each side of the square is about 11 mm. long. The diploë is laid bare. There are two more smaller scars on the top. It is difficult to decide whether these injuries were accidental or caused by a blow. The fragments of Skulls II and III exhibit no further damage.

The most characteristic injury is observable on the fragment Skull IV (Pls. 20f; 21b, e). Almost the entire right parietal bone from the sagittal suture beyond the temporal line and from about 25 mm. behind the coronal suture, backward to the lambdoid suture (about 48 square mm.) is occupied by a large scar. The superficial layer of the external table is missing; the exposed surface consists of uneven islands of small irregular tuberosities, alternating with spots of smooth depressions. In addition, a band-like area extends along the entire lateral border of the injury (Pl. 21b, e); it is striated by narrow, parallel, transverse grooves. Its border on the anterior median side consists of a rounded, rampart-like elevation. Since these structures extend without change along the lambdoid suture from lambda to asterion (Pl. 21b), the injury may possibly have extended to the missing occipital squama. Of special importance is the lateral margin of the injury. This margin, a sharp, curved crest cutting into the bone, attains a height of 4 mm. towards the posterior end of the incision. There is no evidence to indicate that the bone was perforated or that the injury affected the cerebral side

which is normal and has neither a depression, fracture, nor any other alteration. Therefore, it admits of no doubt that the change in the bone structure results from a lesion with its characteristic formation of granulations and newly built bony substance such as are produced by any ulcer of a bone in a healing state. We can only speculate as to the cause of the inflammatory process, but the sharp incision bordering the lateral side of the scar suggests that the head was struck by a keen implement that cut away both the scalp and the superficial layer of the external table of the bone by a shearing movement from right to left, parallel to the striation just described.

Skull VI (Pls. 23c, d; 24b, e) has precisely the same type of injury at the posterior half of the left parietal bone. A circular lesion, about 50 mm. in diameter, extends medially somewhat beyond the sagittal suture and backward to the lambdoid suture. The lesion consists of very irregular tuberosities and, in two places, of deep erosions, none of which perforate the bone. The entire lesion area is circumvallated by a smooth, rounded bone wall. All these details suggest that the lesion was originally an inflamed wound with considerable consumption of bone substance; the smooth surrounding wall indicates that healing had begun at the time of death. In addition to this large injury, there are several smaller ones; one (Pl. 23c), a deep pit just behind the bregma, forms an almost circular hole about 8 mm. in diameter, but does not penetrate the bone; another (Pl. 23d) is on the base on the left side of the nuchal plane. This lesion perforates the bone. But there is no evidence of previous inflammation.

Skull X is badly weathered. An almost quadrangular injury at the left parietal bone (Pl. 27c) lies close to the lambdoid suture. It penetrates deep into the diploë, but has not perforated the bone. Another quadrangular bruise, at the left side of the frontal bone near the coronal suture (Pl. 27c), is a little larger than the first one, but very shallow. The two longitudinal and posterior sides of the square lesion are so well defined that they must have been produced by a blow with a keen implement. It is possible that both these injuries occurred during the excavation.

In considering the causes of these injuries,

we are confronted with the question posed by the absence of the skull bases, the facial bones, and the rest of the skeleton. Except for the two tibiae, no other bone or tooth was found. (See von Koenigswald's report on the discovery and excavation, p. 216.) This fact immediately excludes from consideration the possibility that entire bodies or isolated bones were deposited on the river terrace by flood waters. The bones must have been carried to the site where they were excavated by animals or men. Obviously an animal would not select specific parts of the body or certain bones for such a transportation, so that method can be eliminated. But even if we admit that man himself established this "cemetery," either intentionally or accidentally, we have not provided a reason for the discovery of only skulls lacking faces, or fragments of skulls, and only two tibiae.

We were faced with the same problem in the case of *Sinanthropus*. At first only pieces of skulls, but no limb bones, were found. Breuil and others suggested that the Choukoutien people might have carried uncremated skulls of their next of kin with them and, when they wanted to dispose of them, finally deposited them in the cave (cf. von Koenigswald's report, p. 216). Parallels for this widespread custom are found in Melanesia and Southeast Asia. This explanation, however, lost its validity when the excavations uncovered femurs that were split lengthwise in the same way that paleolithic man split bones to facilitate extraction of the bone marrow for food. Thus the braincase may have been opened from below (foramen occipitale) and the base destroyed for a similar reason, namely, to obtain access to the brain to eat it. In the Solo series, the bases of Skulls I, V, IX, and X are broken out almost completely, but in Skull VI the base is perfectly preserved and in Skull XI it is only partially (orbital roofs) broken out. Apparently Skull I

also had its base when the excavators laid it bare. These facts do not fully support the suggestion that the skull cavity was opened intentionally.

On the other hand, the skulls present unquestionable evidence of violence to the living individuals. Although it may be doubtful whether the minor injuries described above, which penetrated the scalp and partly the bone, are wounds inflicted by man, the large injuries in a state of healing on Skulls IV and VI certainly appear to have resulted from the effect of cutting blows (Skull IV), and the wielding of blunt weapons (Skull VI) in an unsuccessful assault on these people. The fact that these two skulls belonged to young individuals, perhaps females, lends some support to this idea. If this be so, the large cracks in most of the skulls and the breaking out of the skull bases may also be the result of more successful attempts to slay the victims. It is, of course, possible that some of the wounds on top of the head were caused by falling stones during volcanic eruptions, but we have no evidence of such an event.

In all probability, neither the cause of death nor the reasons for the selective interment will ever be established. We may never know whether they were attacked by people of their own kind (a neighboring tribe) or by more advanced human beings who would have given evidence of their "superior" culture by slaying their more primitive fellowmen—a question raised by Boule in the case of *Sinanthropus*. Dr. von Koenigswald suggests that the calottes of the skulls opened from below were used as bowls (p. 216). This would not elucidate the cause of death and the method of interment. But I am doubtful. The rims of these "vessels," as they appear in Skulls I, V, and X, are extremely irregular and bear no evidence of wear as the result of this special use.

MORPHOLOGICAL CHARACTER OF *HOMO SOLOENSIS*

THE SKULL

GENERAL ASPECT

The description of the general form of the skull is based on the six best preserved skulls (Skulls I, V, VI, IX, X, and XI) in the series.

They are, on the whole, surprisingly alike. The greatest difference between them is in the size. The greatest length varies from 221 mm. (Skull V) to 191 mm. (Skull VI); the "greatest breadth" (intercrystal breadth) from 146 mm. (Skull VI) to 159 mm. (Skull X); and the great-

est height (basio-bregmatic) from 122 mm. (Skull VI) to 131 mm. (Skull V). The average greatest length is 201.8 mm.; the average greatest breadth (intercristal) is 152 mm.; and the average greatest height is 126 mm. The length-breadth index ranges from 75.2 (Skull X) to 65.2 (Skull V); the average is 72.3. The highest length-height index is 63.8, the lowest 59.2, and the average 61.6. This uniformity in the Solo skulls makes it possible to select the one that comes closest to the average as the standard form. This is Skull XI, which happens to be the best preserved and with its base almost intact.

Consequently Skull XI was used as a model for the drawings of the skull in lateral, frontal, occipital, vertical, and basilar views (Pls. 33-37, 39-40). Those parts or individual structures of Skull XI which were missing or obscured by damage on one side but well preserved on its opposite side or on other skulls were copied and transferred to the corresponding position on the model. These restorations are so specified in the explanatory sketches which accompany each drawing as separate figures, but they are not marked on the drawings. All views of the model are oriented in the orbitale-porion plane (Frankfort Horizontal). The porion landmark is easily recognizable in each of the six skulls, but in none of them is the lower margin of the orbit preserved. Its location was calculated on the basis of the height of the orbit of *Sinanthropus pekinensis* in which the whole contour of the orbit is intact. This calculated height is about 38 mm.

The drawings were made from the model in orthogonal projection and were executed with the utmost accuracy so that linear distances can be measured on them. Unessential details, such as fractures or injuries, were omitted in the illustrations, but the course of the sutures, their meandering, and the structural irregularities were reproduced as precisely as possible. As the left side of Skull XI is better preserved than the right side, and there is virtually no structural difference between the sides, the left side is shown in the drawing.

NORMA LATERALIS

Plate 30

In general lateral aspect the skull reveals several peculiar features. As a whole, it seems

higher than *Sinanthropus pekinensis* in relation to its length, although the length-height index is only 2.1 units greater in the model skull (61.7) than in the restored *Sinanthropus* skull (59.6). This difference of the Solo skull in appearance results from the more acute slope of the frontal squama, from the bregmatic elevation towards the glabella, and the almost immediate merging of the squama into the supraglabellar torus. In *Sinanthropus* the squama has a broad frontal bulge, descending nearly vertically, but it is separated from the torus by a very distinct sulcus supratotalis. Another characteristic feature of the Solo skull is the great distance between glabella and nasion and the nearly vertical course of the contour between these two landmarks.

The skull is characterized by a heavy, pronounced occipital torus, which in principle is the same formation as that observed in *Sinanthropus*, but quite different from it in detail. The course of the outline of the top of the calvarium is also of special interest. It recedes directly from the glabella in a slightly undulant line in the direction of a moderate swelling around the bregma (protuberantia bregmatica). The bregma elevation marks the highest point of the calvarium in the Frankfort Horizontal, the "vertex" almost coinciding with the bregma. Behind it the outline descends gradually towards the lambda. Between the middle and the last third of the bregma-lambda arc a moderate swelling (protuberantia obelica) merges into a slight depression (depressio postobelica). The lambda, like the bregma, is located on a second bulge (protuberantia lambdoidea), followed again by a slight depression (depressio supratotalis) that rises again to the torus occipitalis. Beyond the torus the outline turns sharply forward towards the mastoid region. This undulating contour, elevations alternating with depressions, is present in, and a characteristic feature of, all the Solo skulls.

The glabella in front and the inion (occipital torus) in the rear are the most projecting landmarks (cf. Fig. 5). The greatest length of the calvaria coincides with the glabella-inion line. There is no other "opisthocranium" but the inion.

The supraorbital torus terminates in a very thickened zygomatic process. Its upper corner continues into a pronounced temporal line

which takes the form of a wide arc, almost parallel to the contour of the calvarium. Towards its end, the temporal line broadens into a distinct, elongated bulge, filling out the posterior part of the mastoid angle of the parietal bone. This bulge is identical with the torus angularis of *Sinanthropus*, although in the latter it is more circular, circumscribed, and, as a whole, more bulging, and less distinct in its connection with the temporal line.

In comparison with Neanderthal or modern

facies temporalis of the sphenoid, the bottom of the fossa, is almost entirely preserved and terminates in a very sharp crista infratemporalis, below which the processus pterygoideus is visible, especially the lateral lamina. The processus extends forward in an oblique direction. The surface of the squama temporalis has finer and broader lines from which muscular bundles of the deep portion of the temporal muscle apparently took their origin. All lines converge in the direction of the infratemporal

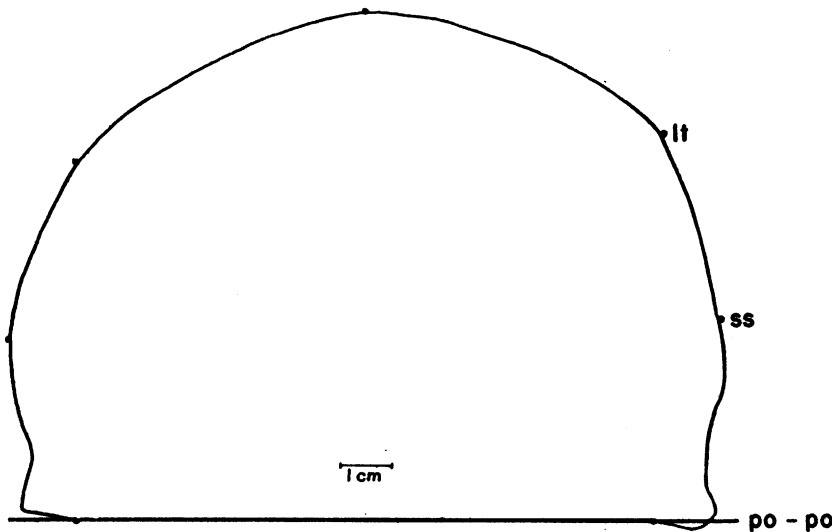


FIG. 11. Interporial coronal craniograms of Solo Skull VI. *Abbreviations:* lt, temporal line; po-po, interporial axis; ss, sutura squamosa.

man, the area of the temporal muscle (planum temporale) is relatively flat so far as the parietal bone itself is concerned. The squama of the temporal bone has the typical triangular form like that of *Sinanthropus*. The crista supramastoidea, a strongly developed ridge forming the inferior side of the triangle, meets the squamosal suture, the superior side of the triangle, at an angle of about 60°. The squamosal suture continues to the pterion in a generally straight line. The high, well-curved arc typical of modern and Neanderthal man does not occur. The anterior side of the triangle, represented by the sphenosquamosal suture, is almost vertical. The whole anterior border region of the squama is curved inward, taking part in the formation of the deep fossa temporalis and representing its posterior wall. The

region. The zygomatic process of the temporal bone is very marked; its base is drawn out to a wide and deep, trough-like sulcus. The process is separated from the supramastoid crest by a distinct depression, although the crest is the direct continuation of the process.

The porus acusticus externus is almost circular and rimmed by a broad wall, with its maximum thickness at the floor of the meatus. The mandibular fossa in front of the porus has the appearance of a very narrow notch when observed from the lateral side. At the outside of the squama, which bridges the incisura tympanica, is a short, linear incision, slightly overlapped by the lateral margin. This can be equated with the spina suprameatus of modern man. The mastoid region is notable for a large and prominent mastoid process. Its surface rises

to a broad, crest-like elevation (crista mastoidea) which runs upward towards the parieto-mastoid suture. There are vestiges of a sutura squamomastoidea which has its source at the incisura parietalis and is traceable almost to the apical region of the process. The crista supramastoidea ends abruptly at the squamosal suture; it is separated from the crista mastoidea by a deep sulcus (sulcus supramastoideus). The postmastoid and asterion regions are fairly rugged, chiefly due to the presence of a number of small and large ossa Wormiana, partly isolated, partly fused, and intercalated into the parieto-mastoid, lambdoid, and occipito-mastoid sutures. There is a large foramen mastoideum. Behind the mastoid process, the mastoid incisure appears in the form of a narrow cleft. Farther back, a second cleft separates the crista paramastoidea from the crista occipito-mastoidea. The occipital torus ends just below the asterion in a large bulge (processus retromastoideus). (For all these details compare Pls. 33, 34, 39, 40.) Behind it, the deep impressio muscularis of the nuchal plane is visible and, beyond, the marked crista occipitalis externa.

In lateral view, the recognizable sutures are the naso-frontal, the fronto-maxillar, and the fronto-lacrimar. They are partly fused. As mentioned above, the nasal process of the frontal bone is very high. Throughout almost its entire length the coronal suture is of the linear type; it bends sharply forward where it reaches the temporal line (stephanion), runs along this line for a short distance, and bends downward again to the pterion. In contrast to the human pattern of the pterion in *Sinanthropus*, in Solo man it is typically "simian." The temporal bone has developed a broad and very distinct frontal process that separates the parietal and sphenoidal bones by making contact with the frontal bone. The sphenofrontal suture passes forward and downward from the pterion to the sphenozygomatic suture. The processus zygomaticus of the frontal bone is entirely preserved up to the spheno-frontal suture. The zygomatic bone is broken off along these two sutures and is missing. The squamosal, the coronal, and the lambdoid sutures are of the same linear type. Only the parieto-mastoid suture takes a winding course, enclosing some fused Wormian bones as mentioned above.

NORMA FRONTALIS

Plate 35

Viewed from the front, the course of the outline of the Solo skull is very characteristic. Its greatest lateral projection is at the level of the supramastoid crest. Below this crest the outline bends inward, following the contour of the mastoid process (cf. norma occipitalis, Pl. 36), and above this mark it also turns inward, receding gradually in the same direction up to the temporal line where it makes a second fairly sharp bend towards the elevated mid-line. This mid-sagittal elevation represents a crista sagittalis. In other words, the skull reaches its maximum breadth at the bi-auricular plane and decreases gradually towards the top. As Skull XI, which served as model, is lightly depressed on the left side, this condition is more clearly observable on the right side. The form of the calvarium as indicated by the outline is exactly the same as that of *Sinanthropus* and differs from that of any Neanderthal skull (cf. Fig. 23). As in *Sinanthropus*, a well-developed parasagittal depression lies between the mid-sagittal crest and the temporal lines.

A further peculiarity of the Solo skull in frontal view is the lowness of the forehead as compared with the total height of the calvarium above the bi-auricular (porion) level. The forehead itself is evenly vaulted; it has no marked frontal tuberosity nor any trace of a special median crest.

The most conspicuous features are the supra-orbital tori which, contrary to the condition observed in *Sinanthropus*, do not form a continuous cross bar at the base of the forehead. They are separated by a distinct depression in the glabella region, that is to say, no distinct torus glabellaris or supranasalis unites the supraorbital tori of either side. The right and left tori bend downward, when they reach the nasal process of the frontal bone and unite below the glabella to form a prominent nasal bridge. Only the uppermost parts of the nasal bones are preserved; there is no indication of a distinct notch between the nasal bones and the frontal bone (cf. lateral view, Pl. 33). The supra-orbital tori are very thick and project markedly both forward and sidewise. Their upper surfaces merge gradually into the frontal squama without a distinct sulcus supratoralis as in

Sinanthropus. The tori are thickest in their lateral ends; the thickness is maintained throughout the entire zygomatic process. The temporal line which has its origin at the corner begins with a broad, high crest that flattens gradually as it ascends in the direction of the stephanion. The median and middle portions of the tori are almost equally robust; there is only a very slight depression between these two portions. The orbital margin forms a wide, flat arc, rounded throughout. Near the median end

The facies temporalis of the ala magna of the sphenoid which forms the base of the fossa is concave. It ascends towards the temporal squama and is covered with parallel ripples from front and above downward and backward (Pl. 35a, right side). The zygomatic process of the temporal bone rises from the temporal wall with a wide, trough-like sulcus, as described above. Behind its root the crista petrosa appears as a transverse wall; the mastoid process is discernible (Pl. 35a, right side) farther back.

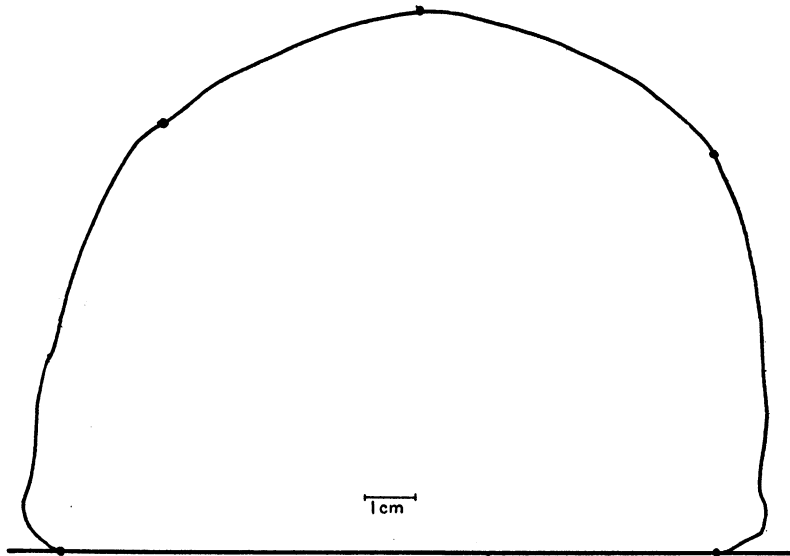


FIG. 12. Interporial coronal craniogram of Solo Skull XI. For landmarks, see Fig. 11.

the margin has a relatively deep, wide notch with rounded contours, the incisura frontalis. The lateral end of this incisure is marked by a distinct tubercular elevation of the margin which I call processus supraorbitalis. Nowhere is there any indication that the margin is perforated by a special foramen or canal (foramen supraorbitale). The incisure, however, is a constant feature in all the skulls in which the supraorbitals are preserved. The nasal process between the two orbits (nasal saddle) is wide and equally rounded. All the sutures that separate it from the nasal, maxillary, and lacrimal bones lie nearly at the same level. The nasal bones do not encroach on the frontal bone.

The distance to which the tori project laterally causes the temporal fossa behind and the postorbital constriction to appear very deep.

The paries superior of the orbit does not differ essentially from that of modern man. The facies orbitalis of the zygomatic bone is not preserved and the paries inferior and the whole maxillary bone are broken off. This has laid bare the parts of the sphenoid viewed from in front: facies orbitalis of the ala magna, corpus and pterygoid processus. The superior orbital fissure is of special interest. It is an oblong hole, not much larger than the optic foramen; a very short slit extends laterally from this hole, separating the paries superior and lateralis of the orbit. The anterior view of the corpus sphenoidalis shows the sphenoidal rostrum with a part of the vomer and at either side of the rostrum, the apertura sinus sphenoidalis. Lateral to the corpus the facies sphenomaxillaris, the opening of the foramen rotundum (laterally) and that of

the canalis vidionus (medially), are easily recognizable. The medial and lateral laminae and the fossa pterygoidea between them are broken off in part from the processus pterygoideus. All these structures are much more robust, that is, the bones forming them are much heavier, than in modern man; however, their general aspect and orientation to neighboring structures do not differ essentially.

The basilar facies of the occipital corpus is visible behind and below the vomer and the pterygoid and the arched upper contours of the

lower portion of the calvarium compared with its upper portion at the level of the parietal tuberosities. The outline also emphasizes the sharp inward bend of the mastoid process and its robustness on the whole, the crista sagittalis at the top and the parasagittal depression, and, finally, the second bend in the line where the temporal line intersects the parietal tuberosity. In height the calvarium is identical with that of *Sinanthropus* (cf. Fig. 23), but much lower than in modern and Neanderthal man.

The occipital bone presents the most inter-

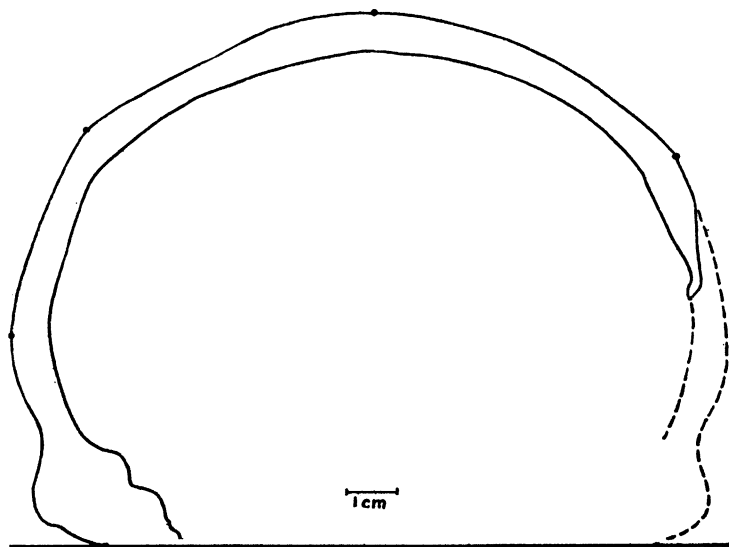


FIG. 13. Interporial coronal craniogram of Solo Skull I. Broken line restored. Inner contour of the braincase indicated. For landmarks, see Fig. 11.

choanae. The straight line which marks its end forms the margin anterior to the occipital foramen. It is flanked by the two condyles with their articular facets turned laterally. The distance between the condyles and the breadth of the occipital corpus and the foramen are much greater than in modern man.

NORMA OCCIPITALIS

Plate 36

The characteristic form of the calvarium as seen from the front becomes much more pronounced in the occipital view (cf. Fig. 22). The enormous bulge at the upper mastoid region clearly demonstrates the great breadth of the

esting feature. The squama is sharply divided into the upper planum (planum occipitale) and the lower one (planum nuchale). The broad projecting structure marking the division by crossing from asterion to asterion is the occipital torus. Its lower margin overlaps the nuchal planum with a sharp, enormously thickened edge. It attains its maximum development at the mid-line in a special triangular prominence which corresponds in its location to the protuberantia occipitalis externa of modern man, but differs characteristically from this structure in its form. Laterally the torus edge ebbs a little, then swells again near the asterion region—a corresponding tuberosity in modern man

has been described as the processus retromastoideus (Waldeyer). It finally bends downward and ends with a distinct ridge lateral to the condyle (cf. Pls. 39, 40). I call this terminal ridge crista occipitomastoidea because both the occipital bone and the mastoid portion of the temporal bone contribute to its formation and the occipito-mastoid suture passes along the ridge. In other words, the torus line forms the frame of an almost circular planum nuchale. Laterally from the terminal end of the ridge and parallel to it is a second one, the crista paramastoidea, and farther along, laterally, is the mastoid process the medial surface of which continues in a narrow indentation, the incisura mastoidea (cf. Pls. 39, 40). In so far as it is visible from behind, the nuchal planum is longitudinally divided by a very pronounced crista occipitalis externa into two remarkably deep fossae which flatten out towards the basilar outline. The foramen occipitale and both its posterior and anterior margins are recognizable. It is flanked by two distinct prominences, which I call tuberositas postcondyloidea (see p. 264). They mask the condyles, the tops of which are barely visible behind them.

The superior limit of the torus occipitalis is much less distinct than the inferior. It is marked only by an irregular furrow, more pronounced on both sides than in the middle. The middle portion, a rough irregularly outlined area, resembles an artificially eroded surface. It is found at the same spot in Neanderthals and is a characteristic sign of the disintegration of the torus, as I have shown earlier.¹ The transverse furrow evidently corresponds to the sulcus supratoralis of *Sinanthropus* and the linea nuchal suprema of modern man. The squama occipitalis above the furrow bulges slightly for its entire length, but the bulge increases in its middle portion (protuberantia lambdoidea) laterally.

The parietal bones curve to the same degree as in *Sinanthropus*. The temporal lines cross slightly below the well-developed tuberosity and run downward and gradually swell into a broad, rounded ridge which ends in the torus angularis. This torus passes over the lambdoid suture, but does not merge into the occipital torus itself from which it remains separated by a narrow notch.

¹ Weidenreich, 1940.

The lambdoid section of the sagittal suture meanders only slightly. A typical os apicis is inserted at the lambda in the lambdoid suture. Then it runs slightly obliquely in lateral direction and bends sharply downward before it reaches the temporal line, and then bends again laterally to and at the asterion, after having crossed the torus angularis. Its continuation into the sutura occipitomastoidea has only one peculiarity; on the left side where a Wormian bone is inserted, a short sutura mendosa deviates in median direction. This suture parallels the lower edge of the occipital torus for a distance of about 30 mm. It is not clear whether the suture ends there or continues along the transverse furrow, described above, to the right asterion region. Some noticeable irregular linear impressions may be traces of such a suture. In Skull V the conditions are similar.

The mastoid area has a distinct foramen mastoideum on both sides.

NORMA VERTICALIS

Plate 37

Viewed in norma verticalis, the Solo skull as a whole agrees with Sergi's sphenoid, but with the supraorbital structure eliminated it becomes rather more ovoid. It conforms to the shape of *Sinanthropus*, differing from it only in its greater size (circumference).

On the sides, the region of the crista supra-mastoidea and the zygomatic process of the temporal bone project, as might be expected from the low location of the greatest breadth as shown in the frontal and occipital views of the skull (Pls. 35, 36). Together with a correspondingly marked projection of the zygomatic process of the frontal bone, this suggests that the Solo skull must have been pronouncedly phenozygous.

The sagittal crest is most developed in the area immediately posterior to bregma. The torus occipitalis and the depression above it are recognizable. Along the supraorbital tori the front contour forms an almost straight line, curving backward at the root of the zygomatic process of the frontal bone (cf. Fig. 25). The temporal lines are very distinct. Where they rise from the zygomatic process of the frontal bone and again near their posterior ends in the asterion region (torus angularis) they have the character of ridges.

NORMA BASILARIS

Plates 38-40

The norma basilaris illustrated in Pls. 38-40 and described here is the first documentary example of the base of an early hominid. The base, on the whole, is excellently preserved and almost complete in Skulls VI and XI. Moreover, this part of the skull is better preserved and more complete than in any skull of Neanderthal man. It reveals details hitherto unknown, as well as characteristic differences when compared not only with modern man but also with Neanderthal man. Since there are also interesting differences between the bases of the two skulls (VI and XI), both basilar views are illustrated and both skulls will be described.

The most conspicuous features of Skull XI (Pl. 39) are the supraorbitals and the markedly projecting zygomatic process of the temporal bone preserved only on the right side. The supraorbitals show the broad, rounded superior margin of the orbit, the incisura frontalis, and the processus supraorbitalis (cf. Pl. 35). There is a large frontal sinus on either side, with a median septum between. But the sinuses are restricted to the interorbital region and, as in *Sinanthropus*, do not extend laterally into the roof of the orbits proper. Furthermore, there is no trace of a circumscribed fossa lacrimalis. The medial orbital wall and the ethmoidal region are broken off in Skull XI, but in Skull VI (Pl. 38) they are present, although slightly damaged. They will be described below.

The base of the sphenoid is best preserved in Skull VI (Pl. 38b). The corpus of the sphenoid is visible with the vomer and the alae vomeris attached to it, and the entrance (right and left side) of the sinus sphenoidalis can be observed. Traces of the ossified synchondrosis sphenoccipitalis are observable in three curved lines crossing the corpus of the sphenoccipital behind the alae vomeris. The roots of the pterygoid process and the upper parts of the medial and lateral laminae are almost completely preserved. Contrary to the condition in modern man, all these structures are formed by very thick bony plates. The foramen ovale (Pl. 39) is a wide opening, circular or oval, but not slot-like, in contrast to its usual form in modern

man. The foramen actually lies at the bottom of a large pit, its borders forming a thick rim. The bottom of the pit has two outlets; the larger one, the foramen ovale proper, is situated on its lateral, posterior side, the smaller one on the medial, anterior side, almost obscured by the rim. A narrow rounded septum separates the two outlets. Such a "foramen accessorium" is recognizable on either side in Skull XI; in Skull VI, only on the left side. Posterior and slightly lateral to the pit is the foramen spinosum behind which the spina angularis rises. It is not clear whether the spheno-temporal suture, with its course easily traceable down to the infratemporal plane, runs laterally to the foramen spinosum and the angular spine, or laterally to the foramen and medially to the spine, or whether it crosses the spine. In all four available cases (Skulls VI and XI), the suture is fused, but the fine cracks in the whole bone surface make it difficult to determine its true character.

The base of the temporal bone is very typical. As I have demonstrated in my paper on *Sinanthropus*, the base of this bone differs characteristically in its arrangement and in the detailed structure of its four constituents (squamosal, tympanic, petrosal, and mastoid portions) from those of the Neanderthals and modern human types. All the features of the Solo skulls present evidence of their identity with those found in *Pithecanthropus* and *Sinanthropus*. The mandibular fossa is very deep and very narrow, with its anterior wall ascending steeply. The posterior wall formed by the tympanic bone is also steep, with prominent crista and spina petrosa. The styloid process is absent; instead a long, narrow groove (sulcus processus styloideus) leads to a small deep pit. Lateral to this pit is a second, more distinctive groove, the foramen stylomastoideum.

The porus acusticus externus lies some distance inward from the outer wall of the calvarium and the bi-auriculare; in other words, there is an "antrum," its roof (tegmen) formed by the squamosal bone. I have called this formation tegmen pori acustici. None of the skulls has a true processus postglenoidalis.

The base of the pyramid that is exposed from the entrance to the carotid canal to the apex has a slightly rough surface; two crest-like lines, one lateral, the other medial, run along

the pyramid almost to its end. There is no evidence of "erosion," a characteristic feature in Neanderthal and modern man. Furthermore, the pyramid fills the whole space between the ala magna of the sphenoid and the sphenoid-occipital corpus except for a fissure along the anterior third of the latter. The apex of the pyramid is in close contact with the roots of the pterygoid, resulting in a restricted "foramen lacerum." Nor are the apex and the whole apical region of the pyramid reduced to a short eroded stump as in modern man. The lateral

mastoid portion. Whether its apex is broken off as in Skull XI, or is completely intact as in Skull VI, the base conforms to a triangle, with one edge facing backward, one laterally (crista mastoidea), and the third one forward, or medially. The three faces of the triangle are more or less curved. A high longitudinal ridge which represents the "paramastoid crest" rises opposite the posterior half of the medial face. A deep cut (incisura mastoidea) lies between the mastoid process and this crest.

The occipital area of the basilar plane of

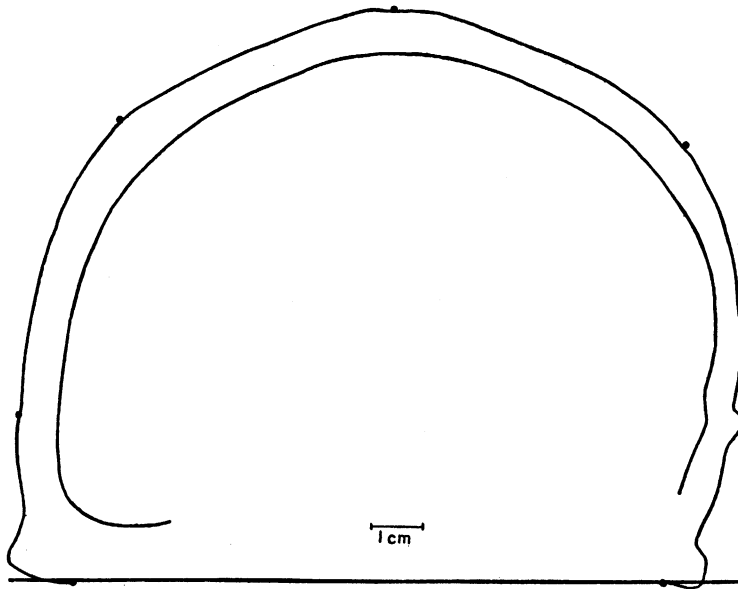


FIG. 14. Interporial coronal craniogram of Solo Skull V; outer and inner contours of the braincase. For landmarks, see Fig. 11.

portion of the pyramid covered by the tympanic bone and the free medial portion form an angle; the lateral portion runs almost in transverse direction, the medial one passes obliquely forward and medially. I have described¹ this condition as a characteristic feature of *Sinanthropus* and as a simian character found neither in any Neanderthalian nor in modern man. In these two hominid forms the axis of the pyramid forms an almost oblique straight line from lateral and back, medially and forward; in some cases the axis may be slightly curved.

A heavy mastoid process can be seen in the

the skull as viewed from below has the occipital foramen as its center. The entire margin of the foramen is intact in both Skulls XI and VI. In Skull VI only the left condyle is preserved. The right condyle and both condyles of Skull XI are broken away, but their bases are preserved, permitting an estimate of their size and location. The two foramina are not identical in form; that of Skull XI is a very elongated and almost regular oval; that of Skull VI is more triangular, with a broad, slightly curved anterior margin and a narrow, recess-like notch at its posterior end. The condyles rising near the anterior end of the foramen are very small compared with the size of the foramen itself and that of the whole skull. On either side,

¹ Weidenreich, 1932.

immediately behind the condyles, are large, irregular tuberosities which I have called *tuberositas postcondyloidea*. The position of the foramen is of special interest. As a whole, it does not lie farther back than in *Sinanthropus* but, as will be considered later, the often discussed question of its location is posed again in a quite different light as we have before us for the first time the intact foramina in early hominids. Its position depends upon the degree of the incline and on the character of the nuchal plane. In the Solo skulls this plane is almost

plane (the opisthion to inion). In other words, the postcondylar portion of the foramen is incorporated in the nuchal plane and faces backward as does this plane.

The corpus of the occipital bone is wide and becomes still wider towards the foramen occipitale. Its surface is irregular. In the mid-line, just halfway between basion and hormion, Skull XI (Pl. 39) has a small foramen, the entrance to a canal. At the edge on either side is a small but very distinct tuberosity (*crista muscoli basioccipitalis*). Immediately behind

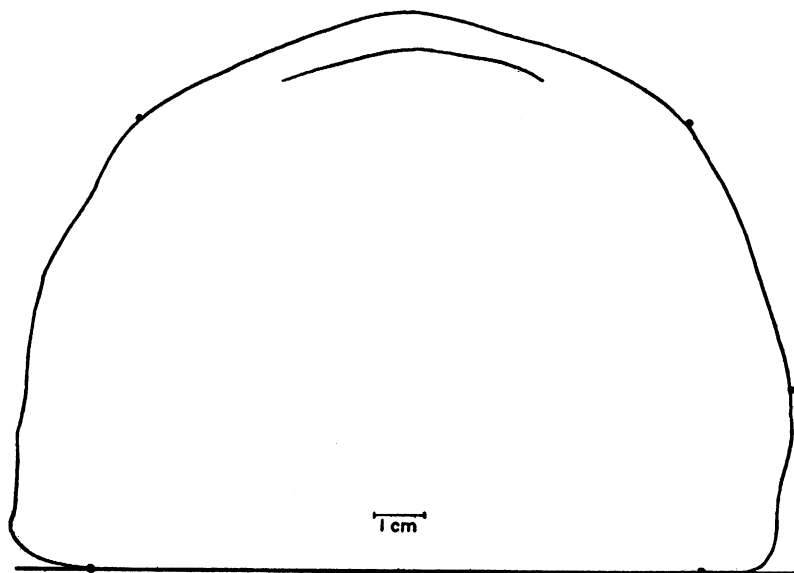


FIG. 15. Interporial coronal craniogram of Solo Skull IX; inner contour indicated in part. For landmarks, see Fig. 11.

level and forms almost a right angle with the occipital plane; in other words, the nuchal plane with no surface bulging descends fairly abruptly from the inion (opisthocranion) to the opisthion. When the Solo skull is oriented in the glabella-inion horizontal, the sphenoccipital surface of the base is nearly parallel to it from the basion to the hormion. The foramen occipitale plane, as indicated by the basion-opisthion line, faces as a whole slightly backward, but there is a characteristic difference between the anterior and the posterior portion of the foramen (cf. Pl. 42). The anterior (condylar) part is oriented almost in the same plane as the basilar plane (basion to hormion) and faces downward. The posterior (postcondylar) part, however, is oriented in the nuchal

the crista is an entrance to a large pit, with the mouth of the *canalis hypoglossi* on its medial wall. Lateral to this pit is a large *fossa jugularis*, with the foramen jugulare as its outlet on the posterior medial side. An oblong pit on either side in Skulls VI and XI corresponds to the *fossa canalis condyloidei* of modern man in location, size, and form, but an outlet directed towards the *sulcus sigmoideus* or the foramen jugulare could not be located. Between this pit and the base of the mastoid process in Skull XI is another pit on either side, much larger and deeper than the one just described. Separated from the jugular foramen by a distinct and relatively thick septum, its posterior wall is formed in part by the thickened end of the *crista occipito-mastoidea*. A rounded outlet at

the base of each pit leads into the sulcus sigmoideus, close to its junction with the foramen jugulare. Since no descriptions or illustrations for these very characteristic features are to be found in the literature, either for apes, modern or fossil man, I have named the pit fossa post-jugularis. Such a fossa also exists in Skull V (left side, Pl. 44e), but it is not developed in Skull VI (Pl. 38). On the left side of this skull in precisely the same position is a distinct processus jugularis. On the right side the end of

that differentiate the upper portion of the plane from the more complicated relief of its lower portion. Except for these features, the only character worthy of mention is a deep depression between the postcondylar tuberosity and the crista occipito-mastoidea, extending downward and terminating at the processus angularis.

THE SEPARATE CRANIAL BONES

This section is devoted to a description of the individual bones of the Solo skull. Those

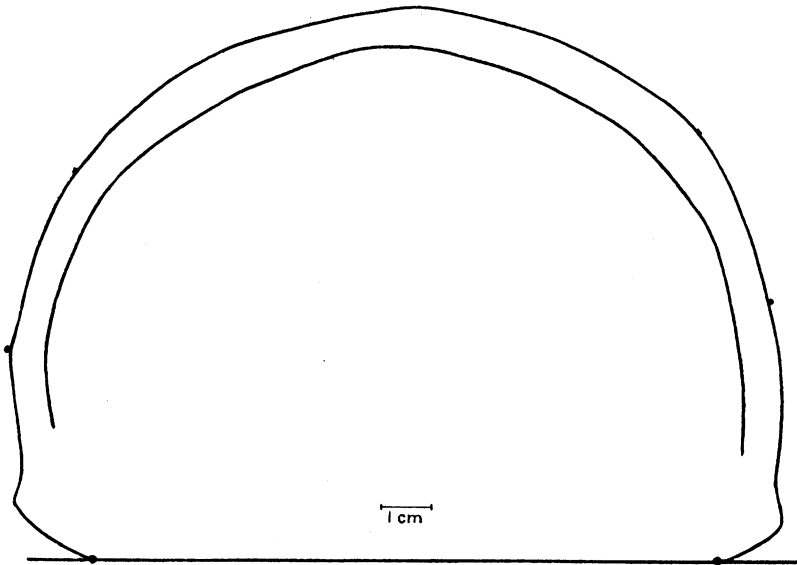


FIG. 16. Interporial coronal craniogram of Solo Skull X; outer and inner contours of the braincase. For landmarks, see Fig. 11.

the crista occipito-mastoidea is depressed so that a small shallow hollow replaces the jugular process of the left side. I shall return below to these features.

The planum nuchale and the crests that encircle it have been described above in so far as they are observable in norma occipitalis (Pl. 36). The basilar view reveals additional details. In contrast to Skull VI, the occipital crest in Skull XI does not extend to the opisthion. However, in both skulls the planum is divided halfway by broad, transverse, band-like swellings which originate at the bordering crest and, in particular, at the region of the processus retromastoideus. They represent the lineae nuchae inferiores in modern man. These swellings demarcate the deep muscular impressions

structures omitted in the preceding general description will be considered here, and others will be elaborated upon. In addition, the individual deviations from the general pattern, as represented by the model skull (Skull XI), will be discussed together with the skull fragments II, III, IV, VII, and VIII.

FRONTAL BONES

Plate 35

The frontal bone of the Solo skull is characterized by two special features: the extraordinary development of the supraorbital tori and the manner in which the torus portion is connected with the squama frontalis. In addition, the Solo material presents, for the first time, an opportunity to study the ontogenetic

development of the tori. Judging from the size and condition of the sutures, Skull fragment II (Pl. 19c-f) is an isolated frontal bone of a child, fragment IV (Pl. 21a-d) that of an adolescent, and Skull XI a fully grown individual.

The frontal bone of the child differs from that of the adult in size, in the degree of the erection of the squama, and in the development of the tori. The greatest breadth of the squama,

TABLE 4

CURVATURE HEIGHT INDICES OF THE FRONTAL SQUAMA OF SOLO SKULLS ARRANGED ACCORDING TO THE RANGE OF THE INDEX (IN MILLIMETERS)*

Solo Skull	Length of the Glabella-Bregma Chord	Maximum Height Above the Chord	Index	Age According to Other Criteria
II	104.0	19.0	18.3	Child
IV	111.0	15.5	14.0	Young adolescent
IX	115.0	16.0	13.9	Adult, advanced age, F
X	106.0	13.0	12.3	Adult, advanced age, F
VI	103.0	10.9	10.6	Adult, F
I	111.0	11.1	10.0	Adult, F
XI	103.0	10.15	9.8	Adolescent ?, M
V	112.5	9.0	8.0	Adult, M

* In the Skull fragments III, VII, and VIII the frontal bone is not preserved.

measured at the stephanion level, is 110 mm. in Skull II, 112 mm. in the adolescent skull, 112 (?) mm. in Skull XI; the greatest length (nasion-bregma chord) in the same sequence is 108, 115, 115 mm., or slightly in excess of the breadth. The upper face width (fmt-fmt) is 101, 115, and 123.5 mm. The thickness of the torus, measured at the lateral corner where it turns down to the zygomatic process, is 6.8, 16.2, and 22.0 mm. This means that the squama of the frontal bone increases 2 mm. at its greatest breadth, or 1.8 per cent, 7 mm. in its greatest length, or 6.5 per cent, from childhood to the adult stage, while the supraorbital region increases 22.5 mm., or 22.2 per cent, in breadth and 15.2 mm., or 22.3 per cent, in thickness during the same period of life. The extension of the frontal squama depends largely on the expansion of the brain, the growth of the supraorbitals on that of the face, or, more pre-

cisely, on the development of the permanent dentition and the chewing muscles. The percentages of the increases from early childhood to the adult stage give a good numerical illustration of the influence of the two formative factors involved.

Still another problem can be elucidated by a comparison of specimens in the same group, that is, the age of the individuals. In all the apes and men the frontal squama has a much more pronounced bulge in early childhood than in adults, and in adult females compared with males. The degree of this bulging of the frontal squama can be determined by calculating a curvature height index derived from the length of the glabella-bregma chord and the maximum distance of the glabella-bregma arc taken at right angles from the chord. Table 4 shows that the squama of Skull II, which certainly is that of a child, is the most curved (index 18.3). Skull IV, an adolescent, follows, with an index of 14.0. The adult female skulls (IX, X, VI, and I) average 11.7, and the two adult skulls (XI and V), which have been classified as males because of their massiveness and the strength of their muscular relief, have the lowest curvature index, 9.8 and 8, respectively.

The curvature index of the Solo skulls cannot be compared with *Sinanthropus* because the frontal squama of *Sinanthropus* is separated from the glabella region by a distinct supra-glabeular torus, producing quite different conditions, which will be discussed below.

A sagittal (metopical) crest is developed in Skull II (child). Gradually diminishing in height, it extends to the metopion region, below which it fades out completely. No crest is recognizable in Skull IV. A more or less distinct mid-sagittal elevation exists in all the other skulls, but only in Skull V is it very pronounced. In none of the skulls is there a trace of a metopic suture, not even in the glabella region, or below, where it occurs very often in modern man.

On the cerebral side of the frontal squama of all the skulls a broadly based frontal crest has developed (Pls. 19e; 21c). In the child (Skull II) the ridge begins to rise about 20 mm. below the bregma, while in all the others it rises from a point farther down, at about the level of the metopion region. In all cases the ridge is very pronounced but somewhat rounded. Contrary to the condition in modern man, there is no

trace of a division into two lips allowing space for the sagittal sinus. In the skulls in which the lower termination of the ridge is preserved, the condition also differs characteristically from that in modern man. In modern man the crista galli, arising from the ethmoidal bone, ascends along the edge of the frontal crest in close contact with it. The processus alares of the ethmoid embrace the frontal crest, so that a hole, or more correctly a blind canal, the so-called foramen caecum, remains open between them. Nothing like this exists in the Solo skulls. As the ethmoidal bone itself is preserved only in Skull VI, it is impossible to make any positive statement about the crista galli. It is clear from examination of an endocast of Skull VI that the whole region is covered by a layer of matrix. (See section on the occipital bone.) This layer is thin, indicating that the frontal crest does not extend to the very margin of the incisura, but ends some distance before it reaches the margin. Furthermore, no special elevation is observable on the matrix at the point where the crista galli arises in modern man. In those skulls (Skulls I and V) in which the frontal crest reaches its natural end and is not broken off, neither a foramen caecum nor any trace of a crista galli can be found. For these reasons I believe that neither that foramen nor a crista galli, like those in modern man, existed in Solo man. The absence of these features is characteristic of the anthropoids. In the three great apes the lamina cribrosa is at the bottom of a deep oval pit sunk in the floor of the anterior cerebral fossa (cf. Pl. 45, gorilla). The frontal crest ends high up and does not descend to the bottom of the pit. The crista galli, when developed (gorilla), is a low, longitudinal crest that scarcely rises above the level of the pit. Therefore the absence or underdevelopment of a frontal crest and crista galli in the Solo skulls is a "simian" feature. Unfortunately, all this cannot be tested in *Pithecanthropus* because all these parts of the frontal bone are missing. But *Sinanthropus* shows conditions similar to those of Solo man. I said in 1943:

The crista galli is missing in all of the [*Sinanthropus*] specimens. . . . The place where the foramen caecum is expected to be found lies more than 15 mm. below the level of the floor of the fossa [anterior cerebri].¹

¹ Weidenreich, 1943, 32.

It was impossible to decide whether a foramen caecum existed because the areas concerned are partially broken off. But in Skull XI, the place where the foramen caecum is located in man is preserved, but "there is no indication of the foramen."²

The orbital and nasal parts of the frontal bones have large and heavy tori. However, contrary to the conditions in *Sinanthropus*, the tori are not separated from the squama by a distinct sulcus supraorbitalis and glabellaris, but continue into the squama itself without any demarcating impression, except for the lateral halves of the supraorbital tori where they build the zygomatic process (Pl. 35). A very distinct triangular medial depression (depressio glabellaris) in Skull XI marks the separation of the

TABLE 5

THICKNESS OF THE TORUS SUPRAORBITALIS PROPER OF SOLO MAN, MEASURED AT ITS FREE ANTERIOR MARGIN (IN MILLIMETERS)

Skull	Nasal Portion	Middle Portion	Corner Portion
I	16.8	14.2	—
II	—	5.8	6.8
IV	13.5	12.0	16.2
V	16.0	14.1	—
VI	13.5	—	18.0?
IX	—	12.3	18.0
X	14.2	11.0	18.5
XI	14.2	13.5	22.0 left side 19.8 right side

originally uniform torus, as it exists in *Sinanthropus*, into the two supraorbitals and a less distinct median swelling below the glabella. In Skulls I (Pl. 18c) and V (Pl. 22c), the torus is uniform; Skulls IV (Pl. 21d), VI (Pl. 24a), X (Pl. 28b), and XI (Pl. 29b) have the glabellar depression, but this region is broken off in Skull IX. In 1939 I described the appearance of this discontinuity as an indication of the disintegration of the whole structure, which is very pronounced in all the Neanderthal skulls. In Solo man we have additional evidence of the inception of this process.

The supraorbitals are very thick. The measurements given in Table 5 are based on the undamaged tori (right or left). As the thickness

² Weidenreich, *loc. cit.*

varies along the length of the torus, measurements were made at three points, one at the most medial part, at the frontal incisure, one at the middle portion lateral from the incisure, and one at the lateral end, the corner where the temporal line begins. Since the upper surface of the torus ascends towards the squama, the measurements were taken as close as possible to the free anterior margin. In addition to the extraordinary robustness of the tori, on the whole, the figures reveal that the corner portion is the thickest, and the middle portion generally the thinnest, part. This diminution of the middle portion is the first indication of a separation of the torus into two portions, a medial and a lateral one. The depression begins at the incisure and extends obliquely and laterally upward to its upper surface. In Neanderthal skulls the disintegration of the torus is still more pronounced, the oblique depression being wider and more deeply cut. The end result of the process is, as it appears in modern man, the perfect separation into a further reduced medial portion, the so-called superciliary arch or ridge, and a very thin corner portion, which no longer projects laterally but does bend down and appears now as the zygomatic process of the frontal bone.

Some additional features of the tori have not attracted any or, at best, very little attention so far, although they offer splendid evidence of the gradual reduction of the supraorbitals in the course of man's evolution. Seen from above (vertical view, Pl. 36), the anterior contour of the supraorbitals forms an almost straight line (Fig. 25) in *Pithecanthropus* and *Sinanthropus*; only towards the lateral end the outline turns slightly backward a little more in Solo man than in the two former. In the Neanderthals, however, the contour on the whole shows a pronounced forward convexity and a corresponding pronounced retroversion towards the ends. As mentioned above, the supraorbital margin of Solo man has a distinct frontal incisure but no indication of a foramen supraorbitale. The width and depth of the notch vary. It is wide and shallow in Skull X (Pl. 28b), narrow and deep in Skull VI (right side, Pl. 24a). The incisure is already recognizable in the child's Skull II (Pl. 19). The contour of the supraorbital margin viewed from in front shows its edge as a long straight

line (Pls. 29, 35) that curves downward fairly abruptly only towards the lateral ends. This is typical of Solo man. Conditions are similar in *Sinanthropus*, and they must also have been so in *Pithecanthropus*, judging from the corner portion of the left margin in Skull II, the only one preserved. The same condition is found in the Rhodesian skull, but not in any of the Neanderthalian skulls where the contour of the margin is more or less curved. This difference, already noted by Oppenoorth (1937), certainly is related to the disintegration of the supraorbitals. They tend to become more and more a part of the face and the orbit and to conform to the circular contours of the latter. The absence of the fossa lacrimalis in Solo man, *Sinanthropus*, and *Pithecanthropus* also indicates that the tori serve not only as a part of the bony capsules for the protection of the eyes but as a strong, rigid outpost of the basilar reinforcement system of the braincase, as has been shown in an earlier paper.¹

The frontal sinuses, a very characteristic feature of Solo man, are present in all the skulls and already recognizable in the child, Skull II (left side, Pl. 19c). In all the skulls they occupy the interior of the glabellar torus proper. A very thin wall on the cerebral side is formed by the braincase itself, and there is a somewhat thicker one on the outer side. In all the skulls a right and left sinus is separated by a relatively thick septum. The dimensions of the sinuses can be given only for the three skulls (Skulls IV, X, XI) in which the sinuses are laid bare. The width for each side varies from 19 to 25 mm. and the length (anterior-posterior diameter) from 14 to 18 mm. As the floors of the sinuses are broken off in all cases, the measurement of the height (vertical direction) gives only an approximation, not the actual height; the maximum height is 17 mm. The sinuses of Solo man are therefore much larger than those of *Sinanthropus* in which only the juvenile Skull III has developed a large sinus. I stated with regard to this condition:

The sinuses neither extend upwards nor forwards to the glabellar region nor laterally into the supraorbitals proper or the roof of the orbits. In reality, they thus represent cellulae frontales of the ethmoidal bone while true frontal sinuses are missing.²

¹ Weidenreich, 1943.

² Weidenreich, 1943, 31.

As in Solo man the sinuses extend laterally beyond the interorbital region into the roof of the orbit. They resemble those of *Pithecanthropus* more closely than those of *Sinanthropus* with regard to their general size and extension.

The nasal process of the frontal bone is broken away in most of the skulls. It is preserved in Skulls I (Pl. 18c) and VI (Pl. 24a), at least to the extent that the interorbital width is measurable with some degree of accuracy; the width is 27.5 mm. in Skull I, 32 mm. in Skull VI. It is, however, possible only in Skull VI to determine the nasion and the course of the sutures which join the frontal bone. The distance (chord) from the glabella to the nasion in Skull VI is 18 mm. Even in those specimens in which the determination of nasion is somewhat uncertain because of the impossibility of deciding whether the breakage followed the nasal sutures or was above it, the glabellanasion measurement could err only by underestimation. In Skull I, for example, it is at least 20 mm., in Skulls V and X, 15 mm. The average of all these measurements is 17 mm., indicating a very considerable distance between glabella and nasion. In *Sinanthropus* the corresponding distance is a fourth to a third less (cf. Fig. 22).

Another feature characteristic of Solo man is the mid-sagittal contour which extends down almost vertically from the glabella (the skull oriented in the Frankfort Horizontal) and does not bend straight inward as in many skulls of primitive modern man (Tasmanian, Australian, and others). In other words, the profile has no distinct nasion notch. In this regard, too, Solo man comes close to *Sinanthropus*; he even has a more "Greek" profile than the latter.

PARIETAL BONE

Plates 20a, b, 21a, b, f, 25, 33, 34

In *Sinanthropus* it was possible to isolate the parietal bones of Skull III (Black) and Skull XII completely since the sutures uniting them with the adjacent bones were wide open, so that the exact size and form of the bone and its margins were determinable. In Solo man the same conditions existed in Skull VIII (Pl. 25c-f) where the two bones were afterward united in the sagittal suture. Furthermore, and for the same reason as in the *Sinanthropus* skulls, it

was possible to isolate the almost completely preserved right side in *Pithecanthropus* Skull III, which consists mainly of the two parietal bones. As mentioned above, both Solo Skull VII (Pl. 25a, b) and *Sinanthropus* Skull VII consist of the area of the mastoid angle of the parietal bone. These isolated parietal bones and their respective fragments, together with the skulls in which they are completely preserved and joined to the other cranial bones, present an excellent opportunity to study the characteristics of the parietal bone.

In the Solo skulls the parietal is almost rectangular; the margo sagittalis and margo squamosus are almost equal in length; the margo frontalis is the shortest and the margo occipitalis approaches the first two in size. The frontal and the occipital angles (angle at the bregma and angle at the lambda) are almost right angles, while the sphenoid and mastoid angles (angle at the pterion and angle at the asterion) are slightly obtuse. The entire bone is curved; the region (parietal tuber) with the most marked bulge coincides with the center of the bone, but the transverse curve, from the sagittal to the squamosal suture, is considerably higher than the curve in the sagittal direction: the sagittal parietal index (over tuber) is 91.0, the transversal parietal index (over tuber) is 84.2 (measurements taken from Skull VIII). The curvature of the bone, both in sagittal and transverse direction, results from the central position it occupies in the structure of the braincase; it varies minimally throughout the skull series. But it is worth noting that in the relatively young Skull IV the sagittal index is the same as in the older Skull VIII, while the transverse index is higher (80.5). In *Sinanthropus* the sagittal index is 89 in the young Skull III and 92.3 in the older Skull XII, and the transverse index is 81.2 and 88.7, respectively. The differences between the index of the Solo and *Sinanthropus* skulls are so small that no conclusion can be drawn.

There are, however, other more significant differences between these two types. Although in both Solo man and *Sinanthropus* the squamosal suture extends in an almost straight line from pterion to the asterion in contrast with the curved line usually found in modern man, the termini of this sutural line both at pterion and asterion differ in these two forms. When

the parietal bone of Solo man is placed on a level plane with its outer surface directed upward, the four corners of the bone rest evenly on the plane, but they do not do so in *Sinanthropus*. In this latter hominid the sphenoid angle extends farther downward and forward. This means that the pterion sutures in Solo man do not meet in the same way as they do in *Sinanthropus*. Indeed, as mentioned above, the temporal bone of Solo man has developed a frontal process (Pls. 30c, 33) which makes contact with the frontal bone and prevents the sphenoid angle of the parietal bone from reaching down to the sphenoid. This suture pattern is very common among the great apes.¹ In Solo man the frontal process of the temporal bone is very distinct on both sides of Skull XI. The pterion region is missing or damaged in all except Skull VI (both sides) and Skull V (left side). Although the condition is not so clear in these skulls as in Skull XI because of the partial fusion of the sutures, apparently the frontal process is separated from the temporal bone by a special suture, producing an "os pterion" with the character of a Wormian bone and thus preventing the "sphenoid" angle of the parietal bone from extending to the sphenoid in Solo man, as it does in *Sinanthropus*.

As I have shown earlier, the parietal bone of *Sinanthropus* is remarkable for the development of a "torus angularis," a special, rounded bulge that rises above its outer surface at the angle between the lambdoid and the parieto-mastoid sutures. The descending portion of the temporal lines merges into this torus. On isolated temporal bones like *Sinanthropus* Skulls III, VII, and XII, it is easy to measure the thickness of the bone at the angle. The measurements are 17.2 mm. in Skull III, 17.4 mm. in Skull VII, and 14.5 mm. in Skull XII. For comparison, the thickness of the parietal bone at the frontal angle is 9.6 mm. in Skull III, 9.5 mm. in Skull IV, and 9.0 mm. in Skull XII. In Solo man the thickness of the parietal bone at the mastoid angle is 15.9 mm. in Skull IV, 13 mm. in Skull VII, and 17.8 mm. in Skull VIII; at the frontal angle it is 7 mm. in Skull IV and 9 mm. in Skull VIII. The thickness of the bone at the mastoid angle is about the same in Solo man

¹ According to Peters (1931) it is found in 98.5 per cent of 274 gorilla, in 91.3 per cent of 382 chimpanzee, and in 67.7 per cent of 816 orang-utan.

and in *Sinanthropus*. But there is an interesting difference; in Solo man the torus occupies a smaller area of the mastoid angle than in *Sinanthropus* and is restricted to its most inferior and posterior part. A comparison of the angle region in isolated bones reveals that the bulge is in the outer surface in *Sinanthropus* but on the cerebral surface in Solo man.

The outer surface of the parietal bone is smooth. It is crossed by the temporal line a little below the parietal tuber, while in *Sinanthropus* this line reaches the level of the tuber. A normal-sized foramen parietale is recognizable only at the right side of Skull III and the left side of Skull VIII.

On the cerebral surface a sagittal crest and a sagittal sulcus, restricted to the obelion region in all cases, have developed in Skulls I, IV, X, and XI. In Skull VII the sulcus transversus crosses the mastoid angle as it does in modern man. This occurrence has not been observed in *Sinanthropus*. Furthermore, no Sylvian crest is recognizable in Solo man.² Impressiones digitatae and juga cerebralia are scarcely visible and will be described elsewhere. No foveolae granulares (Pacchioni) have been found.

ENDOCAST RELIEF OF FRONTAL AND PARIETAL BONES

The convolution and fissure system are very poorly developed in Solo man, least developed in Skulls I and II, but more details, especially of the frontal region, are recognizable in Skulls V and XI.

The imprints of the meningeal vessels are rather obscure and less distinct than in *Sinanthropus*. It is impossible to tell whether this is a natural condition or the result of some kind of attrition. In all the skulls the anterior ramus of the middle meningeal vessel is much more developed than in *Sinanthropus*, but, except for Skull IV, the side branches of the ramus are less developed. The posterior ramus is better or equally developed in all skulls. In Skull VI the anterior ramus of the right side has many side branches, while on the left side the posterior ramus is more pronounced and more ramified; this is the side with the injury described above.

² Weidenreich, 1947.

OCCIPITAL BONE

Plates 18d, 22d, 24b, 26c, 28c, 29c, 30d, 36

The squama and the basilar parts of the occipital bone are preserved; in Skulls VI and XI both are almost intact. As in all hominids, the outer surface of the squama consists of the upper and the lower scale (planum occipitale and planum nuchale), separated by the occipital torus. The torus marks the lower end of the smooth part of the top at the braincase and the beginning of the rugged portion (nuchal planum) to which the cervical muscles are attached. The extraordinary development and the special morphological character of the torus give the Solo skulls their most characteristic aspect. The torus resembles in part that of *Sinanthropus* and *Pithecanthropus*, in part that of modern man. In *Sinanthropus* and *Pithecanthropus* the torus is a cross bar extending between the two asteria and separated from the occipital planum by a distinct sulcus supratoralis and from the nuchal planum by a sharp edge (linea nuchale superior). The torus of Solo man differs from the *Sinanthropus* type in being less distinctly separated from the occipital squama and in having a greatly exaggerated structure differentiating it from the nuchal planum. While the torus surface continues into the occipital planum with no clear limit to its middle portion (Skull XI), the two lateral portions are set off from the occipital planum by slight, semicircular depressions. In contrast to these conditions, the lower margin of the torus forms a thick ridge that projects far out and overlaps the depressed upper areas of the nuchal planum on each side. In the middle portion, however, where the torus is the thickest, a crest (crista occipitalis externa) emerges from the edge and extends downward along the mid-line towards the occipital foramen, dividing the depressed nuchal area into right and left muscular fossae. This whole arrangement has some resemblance to the conditions at the front of the skull. The muscular fossae, with the overlapping edge of the torus, correspond to the orbits and the supra-orbitals, and the middle portion of the occipital torus to the glabellar torus with the nasal process. The occipital torus extends laterally to the asterion region, where a smaller branch extends towards the mastoid of the temporal

bone, while the main stem bends downward and continues into the muscular ridge bordering the nuchal region.

The general pattern of the torus as just described displays interesting variations. Its robustness is most marked in Skull V and weakest in Skull I. In addition some characteristic differences in the shaping of the torus particularly involve its middle portion and the method of connection with the occipital planum. There is a clear tendency towards the discontinuance of this connection by a reduction of that middle portion. The irregular depression above the torus bulge at the inion region indicated in Skull XI is more distinct in Skull VI and extends over a greater area. At the same time the torus becomes narrower but more salient in antero-posterior direction, and the slight groove marking its separation from the occipital planum (Skull XI) becomes wider and deeper. Skull V and Skull X represent earlier phases of this transformation, while Skulls IX and I represent its final phases. At the mid-line, where the external occipital crest emerges, the ridge is at its highest and broadest and is the equivalent of the protuberantia occipitalis externa of modern man. Except for slight variations in robustness, the lateral portions of the Solo torus show no essential structural changes.

The varying appearance of the middle torus portion in the Solo series represents different phases of its disintegration. Compared with *Sinanthropus* and *Pithecanthropus robustus*, the torus of Solo man, despite its general robustness, is already in a state of disintegration. For additional details the reader is referred to an earlier paper,¹ in which the reduction of this superstructure has been described to its final phase as it appears in modern man. Nothing is left of the torus but, at best, two fine lines, the linea nuchal suprema, originally the upper border, and the linea nuchal superior, representing the lower border, the edge in the case of Solo man or the rim of the muscular impressions of the nuchal planum.

The "irregular depressions" above the middle portion of the torus (Pl. 36), the first indication of the process of reduction, are of special historical interest, recalling the early opposition to the evolutionary theory concerning man and the means by which the existence of fossil

¹ Weidenreich, 1940.

relics of early man were contested. The depression in question was first observed in the Neanderthal skull of Düsseldorf by R. Virchow, who wrote:

At the occipital planum the Neanderthal skull shows a continuous system of depressions and elevations. Above the linea nuchae superior which appears in the middle a shallow depression, instead of a protuberantia occipitalis externa, is a shallow pit measuring nearly 25 mm. in transverse direction. The floor of the pit is covered with tuberosities. To the right a much larger and broader shallow depression approaches the lambdoid suture. This is 25 mm. long and almost 20 mm. wide. The floor is uneven and a low, bony projection like an island arises in its center.¹

Virchow considered this irregularity to be a lesion caused by a long-persisting trauma combined with caries. He used this and other irregu-

TABLE 6

LENGTH-BREADTH MEASUREMENTS (CHORD L-O IN PROPORTION TO CHORD AST-AST) OF THE OCCIPITAL SQUAMA OF SOLO MAN AND *Pithecanthropus robustus* (IN MILLIMETERS)

	Length	Breadth	Index
Skull I	81	127	63.8
Skull V	89	126	70.6
Skull VI	85	123	69.1
Skull IX	84	129	65.2
Skull X	(85?)	(125?)	—
Skull XI	87	(110?)	—
Solo average	85.2	126.2	67.1
<i>Pithecanthropus robustus</i>	79.5	130	61.2

larities of the skeleton that he also regarded as of a pathological nature as evidence that Neanderthal man cannot have belonged to an "early race" of man. He argued that in those early, difficult times, pathological individuals, like Neanderthal man, could not have survived. We know now that rough areas and depressions like those described in the Neanderthal skull occur at exactly the same place in the *Sinanthropus* skulls (especially Skulls III and XI). In the Solo skulls, they are best developed in Skull XI (cf. Pl. 36). They are not ulcerations resulting from a trauma as Virchow, the pa-

thologist, claimed. A comparison with actual ulcerations (cf. Pls. 21e, 24e) reveals that they indicate a quite "normal" process of disintegration of the bony structure characteristic of early hominids. We cannot explain why the reduction of the torus causes a roughness of that part of the occipital planum, but its occurrence in *Sinanthropus* and Solo and Neanderthal men excludes its interpretation as a pathological process. Virchow's further conclusions that the Neanderthal man of Düsseldorf does not differ from the modern human type have long since been proved erroneous.

The occipital squama of Solo man, the upper and lower scale, is very broad (measured from asterion to asterion) and relatively short (longitudinally from lambda to opisthion). Table 6 presents the length and breadth measurements of the chords of the squama and their indices. The minimum-maximum values of the chord index are 63.8 to 70.6, with an average of 67.1. In *Sinanthropus* the minimum-maximum values of the chord index are 71.7 to 76.1, with an average of 74.0. Comparison reveals that in Solo man the chord is shorter than in *Sinanthropus*. However, the difference is minimal, compared with modern man. According to Martin (1928), the chord index of modern man ranges from 81.9 (in brachycephalic skulls) to 98.0 (in dolichocephalic skulls), with an average of 87.3. In other words, in Solo man and *Sinanthropus* the longitudinal extension of the occipital squama lags far behind its

TABLE 7

LENGTH OF THE MID-SAGITTAL CHORDS OF THE UPPER AND LOWER SCALES (L-I AND I-O) OF THE OCCIPITAL SQUAMA OF SOLO MAN AND *Pithecanthropus robustus* (IN MILLIMETERS)

	Planum occipitale (l-i)	Planum nuchale (i-o)	Index
Skull I	57	51	89.6
Skull V	59?	(59?)	(100)
Skull VI	59	52	88.1
Skull IX	56	54	85.1
Skull X	67	(58?)	(86.5)
Skull XI	67	50	74.6
Solo average	61	54?	87.3
<i>Pithecanthropus robustus</i>	44	64	145.2

¹ Virchow, 1872, 158. (Quotation translated from the original. F. W.)

breadth compared with modern proportions, whether the skulls are dolichocephalic or brachycephalic.

The length of the upper scale compared with the length of the lower scale (l-i to i-o) is shown in Table 7. The average index is 87.3, ranging from 74.6 to 100 (?). In *Sinanthropus* the average index is 123. In other words, the planum occipitale is longer than the planum nuchale in Solo man, but it is shorter in *Sinanthropus*. In *Pithecanthropus robustus*, with an index of 145.2, it is even shorter than in *Sinanthropus*. This means that the longitudinal extension of the nuchal planum is much greater in *Sinanthropus* than in Solo man, in spite of the much stronger development of the muscular relief in the latter. Compared with Solo man, the torus structures and the nuchal planum in *Sinanthropus* are much smoother, the planum itself rather convex, while in Solo man the planum is flat or in part even concave.

The curvature of the total squama of Solo man is very pronounced, as can be seen in Table 8. The curvature index ranges from 67.3 to 74.6, with an average of 72.0. In *Sinanthropus* the range is 72.9 to 77.8, with an average index of 74.7.¹ The curvature is, therefore, greater in Solo man than in *Sinanthropus*. Martin² notes an average index of 82.8 for modern man. However, the great difference between the length of the chord and the length of the arc, as expressed by the curvature index, is due less to a greater or lesser curve than to the sharp angle formed by the upper and lower scale of the squama (see below) at the inion.

The whole occipital planum bulges above the supratoral depression up to its lambdoid margin, so that this margin projects somewhat above the parietal bone. This feature is very pronounced in Skull V (Pl. 23a); it is less marked, but still distinct in Skull XI (Pl. 33). As already mentioned, the torus angularis of the parietal bone extends over the lambdoid suture on either side in Skulls XI and IX (Pl. 36). In the latter specimen (Pl. 28c), the torus angularis merges into the lateral portion of the occipital torus, while in Skull XI it is separated by a narrow notch. This feature is

of some interest. The torus angularis marks the termination of the temporal line. In the great apes the sagittal crest, analogous to the temporal line in the hominids, continues into the nuchal crest high up at the "inion" region, and the united sagittal and nuchal crests extend from the "inion" to the mastoid, where they merge into the mastoid crest. In hominids, even where the temporal line and the torus occipitalis are well developed, they remain widely separated, and where they approach each other in the asterion region they usually do not fuse.

The nuchal planum is neither morphologically nor functionally confined to the area of the

TABLE 8

OCCIPITAL CURVATURE INDEX, RATIO OF LAMBDA-OPISTHION CHORD (L-O) AND LAMBDA-OPISTHION ARC (L-O) IN SOLO MAN (IN MILLIMETERS)

	Chord	Arc	Index
Skull I	81	112	72.3
Skull V	89	124	71.8
Skull VI	85	114	74.6
Skull IX	84	114	73.8
Skull X	85?	126?	67.3
Skull XI	87	120	72.4
Solo Average	85.2	118.3	72.0
<i>Pithecanthropus robustus</i>	79.5	110	72.3

lower squama above the foramen occipitale, as ordinarily described, but includes the entire foramen region. It is surrounded by an almost continuous chain of ridges. At the border of the planum occipitale, these ridges are represented by the edge of the occipital torus. A special tuberosity, located halfway between inion and the mastoid process, is the processus retromastoideus mentioned above. (See Pls. 38-40 for this and the following descriptions.) It marks the lateral end of a broad transverse elevation that divides the planum into an upper area (impressiones musculares) and a lower, less depressed area. This dividing elevation corresponds to the "linea nuchae inferior" of modern man which is, in reality, very rarely a "line" but a rough, transverse elevation. The border ridge continues beyond the retromastoid process into the occipito-mastoid ridge which parallels the suture of the same name.

¹ In Table 7 of my paper on *Sinanthropus* (1943) the index is erroneously given as 72.1.

² Martin, 1928.

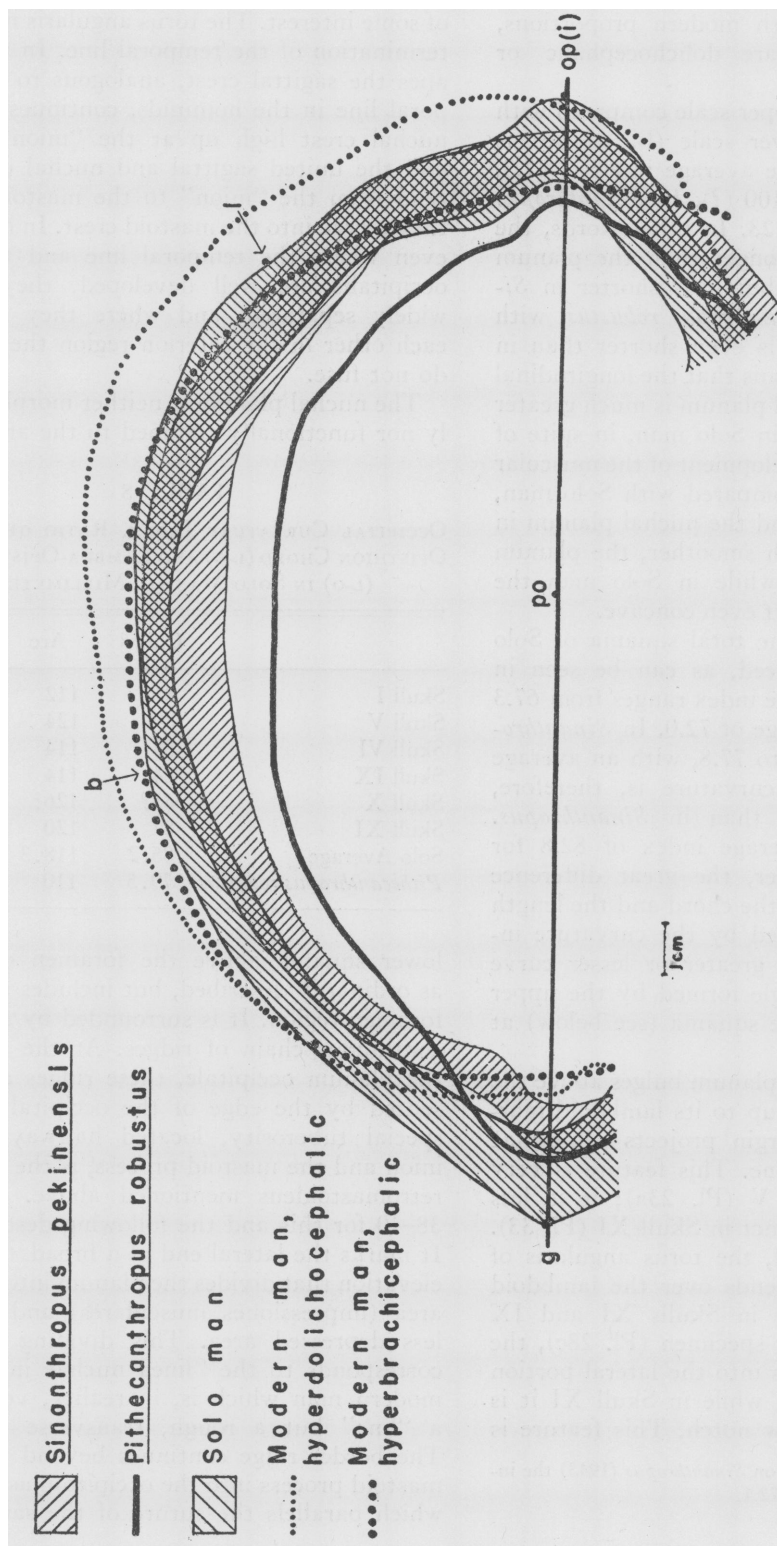


FIG. 17. Mid-sagittal craniograms of *Pithecanthropus robustus* (restored); *Sinanthropus pekinensis* Skulls III, X, XI, and XII; Solo Skulls I, V, VI, IX, X, and XI; modern man, hyperdolichocephalic European of Nordic race; and modern man, hyperbrachycephalic European of Alpine race. *Sinanthropus* and Solo man show the minimum and maximum limits of the expansion of the braincase. All the craniograms are superimposed on the glabella-inion line and the porion, projected to this line. Abbreviations: b, bregma; g, glabella; i, inion; j, lambda; op, opisthion; po, porion.

This crest terminates at the processus jugularis or, as in Skull VI, ends very abruptly at a deep pit immediately behind the foramen jugulare (fossa postjugularis). This chain of ridges encloses an almost circular space, with its transverse diameter a little larger than the longitudinal diameter (105 mm. against 95 mm.). This area has nearly the same form in all hominids; the mastoid process lies just outside the circle. In the anthropoids the mastoid process is enclosed in the circle, the crista supramastoidea representing a part of the bordering ridge. Therefore the planum area in anthropoids is an ellipse, with its transverse diameter the larger one. In modern man the planum is also commonly an ellipse, but even in brachycephalic skulls the longitudinal diameter of the ellipse is the larger in man. This fact is interesting in so far as it demonstrates that neither the development of the cervical musculature nor the form of the nuchal planum itself has any influence on the form of the braincase, as has been suggested.

The foramen occipitale of Solo man is very long (Pls. 38-40) but relatively narrow. The measurements of the foramen of the two Solo skulls in which the entire foramen is preserved are presented in Table 9. The foramen, as a whole, is large; its width is slightly more than three quarters of its length. Considering the fact that the brain of Solo man is smaller than that of modern man, the greater size of the foramen occipitale is noteworthy. The difference may indicate either that the hole is formed in relation to the size of the braincase and not to that of its contents or that the cervical part of the spinal cord of Solo man is relatively larger in comparison with the size of the brain than it is in modern man. In the *Pithecanthropus robustus* skull, which is smaller than that of Solo man, the foramen is shorter, but not narrower; the length is 39 mm. and the breadth 29 mm., the index is 74.2. The foramen is oval and broad in front, as in Solo Skull VI, but has no recess at the rear (see below). The foramen in the Neanderthal type of La Chapelle-aux-Saints is large, but in Saccopastore I it is small. The latter is remarkable because the ratio of breadth to length is closer to that of modern man; the foramen is almost circular. Among the anthropoids, orang-utan with an index between 70 and 80 is closest to Solo man; the foramen

as a whole, however, is smaller. It resembles that of Solo man also in so far as its posterior end has a wide distinct recess. Gorilla and chimpanzee have round foramina, with indices ranging from 80 to 95. The foramen of Rhodesian man resembles that of Solo Skull VI.

The foramen in Skull VI differs in form from that of Skull XI, which is almost oval. In the former the anterior margin is straight and long, while the posterior end narrows and elongates, resulting in a kind of recess. This

TABLE 9

SIZE OF THE FORAMEN OCCIPITALE IN HOMINIDS
(IN MILLIMETERS)

	Length	Breadth	Index
Solo Skull VI	41.0	31.5	76.8
Solo Skull XI	45	29	66.3
<i>Pithecanthropus robustus</i>	39	29	74.2
La Chapelle-aux-Saints			
(Ranke)	46	30	65.3
Rhodesian man (Pycraft)	41	32	78.2
Modern man, average			
(R. Martin)			
Male	32.6	26.5	72.4
Female	37.0	34.3	89.1

recess is very pronounced (Pl. 18b) in Skull I where only the posterior part of the foramen is preserved. The posterior part in Skull XI is distinctly narrower, although not so sharply set off from the foramen as in Skull VI. The recess-like formation, therefore, seems to be typical of Solo man.

All three Solo skulls (VI, XI, and I) in which the foramen is entirely or partly preserved have one singular feature very definitely developed (Pls. 30e, 42). The posterior half of the occipital foramen is clearly turned upward in the same direction as the nuchal planum, while the anterior half is oriented in the same plane as the basilar surface of the sphenoccipital corpus. So far as I know, this type of orientation has never previously been observed in any hominid skull. This feature, together with the flatness and upward direction of the nuchal plane, lends a somewhat ape-like character to the Solo skulls, when compared with other hominids. The angle between the basilar plane and the nuchal plane is between 115° and 120°. (See p. 263.) In other words, the nuchal plane

and the posterior half of the occipital foramen face backward. The corresponding angle in the skull of La Chapelle-aux-Saints is about 155°. The whole question concerning the "position" of the foramen magnum will be discussed later.

The occipital condyle is preserved only on the left side of Skull VI. The right occipital condyle is broken off, but as its base is intact it was possible to reconstruct it, with the left condyle serving as a model. In Skull XI both condyles are broken off, but their bases are preserved, giving some indication of length, breadth, and orientation.

TABLE 10
SIZE OF THE CONDYLUS OCCIPITALIS
(IN MILLIMETERS)

	Length	Breadth	Index
Solo Skull VI, left	18	11	61.1
Solo Skull XI, ^a right	21	10	47.6
Solo Skull XI, left	21	9	42.8
Modern man, average (Sergi)	25.8	13.0	50.3
<i>Pithecanthropus robustus</i> , right	26	13.4	51.6
<i>Pithecanthropus robustus</i> , left	21	13.4	63.7

^a Basis.

The condyles (Pls. 38-40) are located at the anterior end of the foramen; a tangent to their anterior poles passes somewhat anterior to the basion in Skull VI and may be somewhat posterior to it in Skull XI. The condyles are small; the length of the left condyle of Skull VI is 18 mm., its breadth only 11 mm. The dimensions of the right condyle were approximately the same. The measurements of the base of the condyles in Skull XI indicate that they may have had about the same dimensions. The condyles are low, rising only slightly above the margin of the foramen, the anterior end distinctly more so than the posterior end. The longitudinal axis is almost parallel to the mid-sagittal line. The articular facet is oval, the front part being slightly broader than the rear. The facet is turned outward so that its surface forms an angle of about 30° with the horizontal plane. The facet is almost flat in transverse direction but markedly curved longitudinally, its anterior half being almost horizontally

oriented, while the posterior mounts steeply upward as does the posterior half of the foramen (see above). The base of the condyles of Skull XI indicates only that they were located at the anterior end of the foramen. In addition, the condyles were not rounded at their anterior end, but must have tapered towards the mid-line as in chimpanzee.

In *Pithecanthropus robustus* the two condyles differ neither anteriorly nor posteriorly in form, but are sharply set off, tapering in both directions. The right condyle is 26 mm. long and the left 21 mm.; the breadth of both is the same, 13.4 mm. Despite the larger size, the form is approximately the same as in Solo Skull VI. Both articular facets are oval, tapering towards their anterior ends, but broadening posteriorly. The facets are fairly flat, both transversely and longitudinally. A transverse furrow divides the left facet. The longitudinal axis extends slightly obliquely from front to rear and laterally. The condyles are higher in front than in the rear, but the posterior ascent is not so sharp as in Solo Skull VI. The anterior condyle tangent passes behind the basion. Viewed from a mid-sagittal section through the base, the condyle appears as a high tubercle, semicircular in contour, close to the anterior end of the foramen and just below the entrance to the condylus hypoglossus. The condyle is sharply separated from the tuberositas post-condyloidea.

Very little is known about the condyles of Neanderthal man. According to Boule, the condyles of the skull of La Chapelle-aux-Saints are slightly elongated and somewhat salient and flat. Neither measurements nor additional data are given. The only condyle of the Rhodesian man that has been preserved, the left, has, according to Pycraft,

a somewhat remarkable shape, forming a relatively narrow but long trochlear surface, almost semicircular in contour, and turned obliquely outwards from the middle line.¹

Measurements are not given, but position and form appear similar to those of Solo man. The condyles of the Saccopastore Skull I are small and pronouncedly convex in oblique anterior-posterior direction, according to S. Sergi.²

¹ Pycraft, 1928, 5.

² Sergi, 1944.

The condyles of modern man display a great variety of forms. Strecker¹ described three types: Type I, low, the sagittal diameter smaller than the transverse diameter, curvature moder-

than the transverse; Type III, intermediate between Types I and II. Strecker designates Type I the Negro type, Type II the Asiatic type, while Type III occurs in all races.

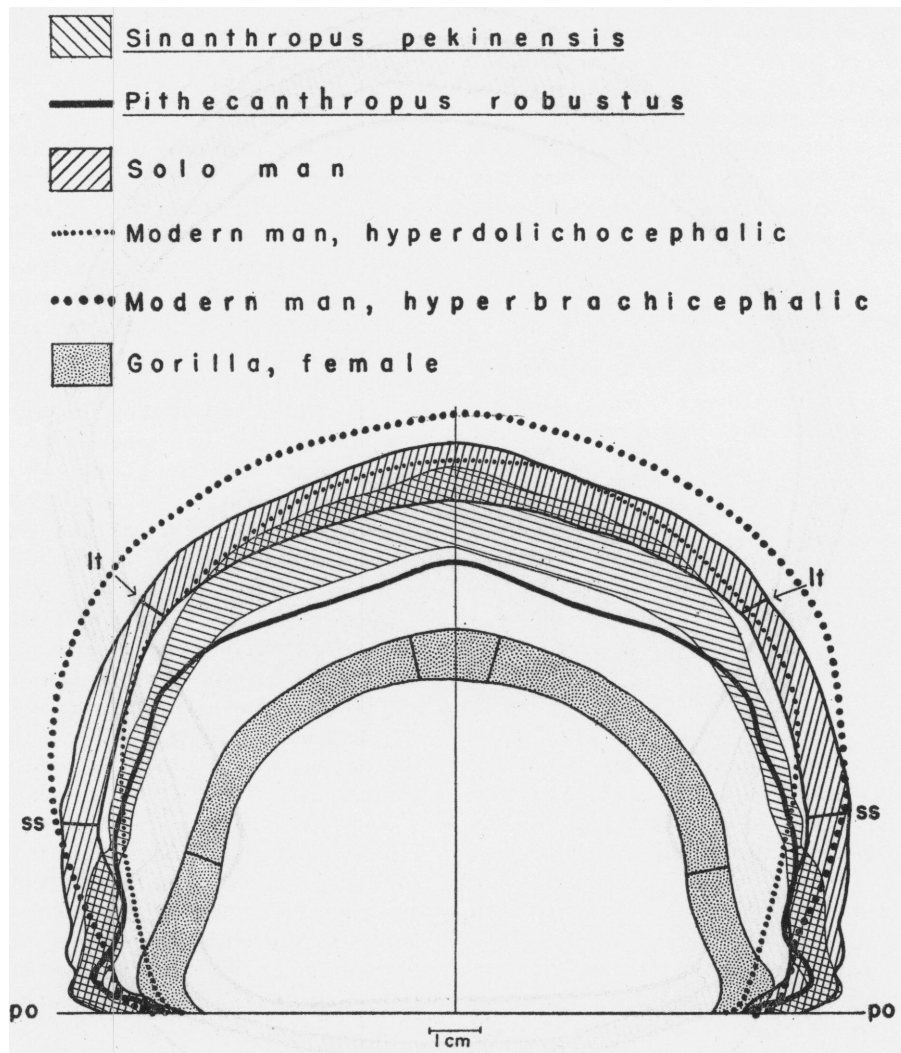


FIG. 18. Interporial coronal craniograms of *Pithecanthropus robustus* (restored); *Sinanthropus pekinensis* Skulls III, X, XI, and XII; Solo Skulls I, V, VI, IX, X, and XI; modern man, hyperdolichocephalic European of Nordic race; modern man, hyperbrachycephalic European of Alpine race; and female gorilla; all superimposed on the center of the interporial axis (po-po). Abbreviations: lt, position of the temporal line; ss, sutura squamosa.

ate in both directions; Type II, high, the sagittal diameter much longer than the transverse one, longitudinal curvature more pronounced

¹ Strecker, 1887.

The condyles of gorilla and chimpanzee differ from those of Solo man in being much larger in relation to the size of the foramen magnum. In Solo Skull VI the condyle length is 44 per cent of the length of the foramen

occipitale, and the breadth is 35 per cent. In a large male gorilla in the American Museum of Natural History collection, the figures are

53 per cent. All three anthropoids also differ in the orientation of the condyles. In gorilla and chimpanzee the condyles are higher and

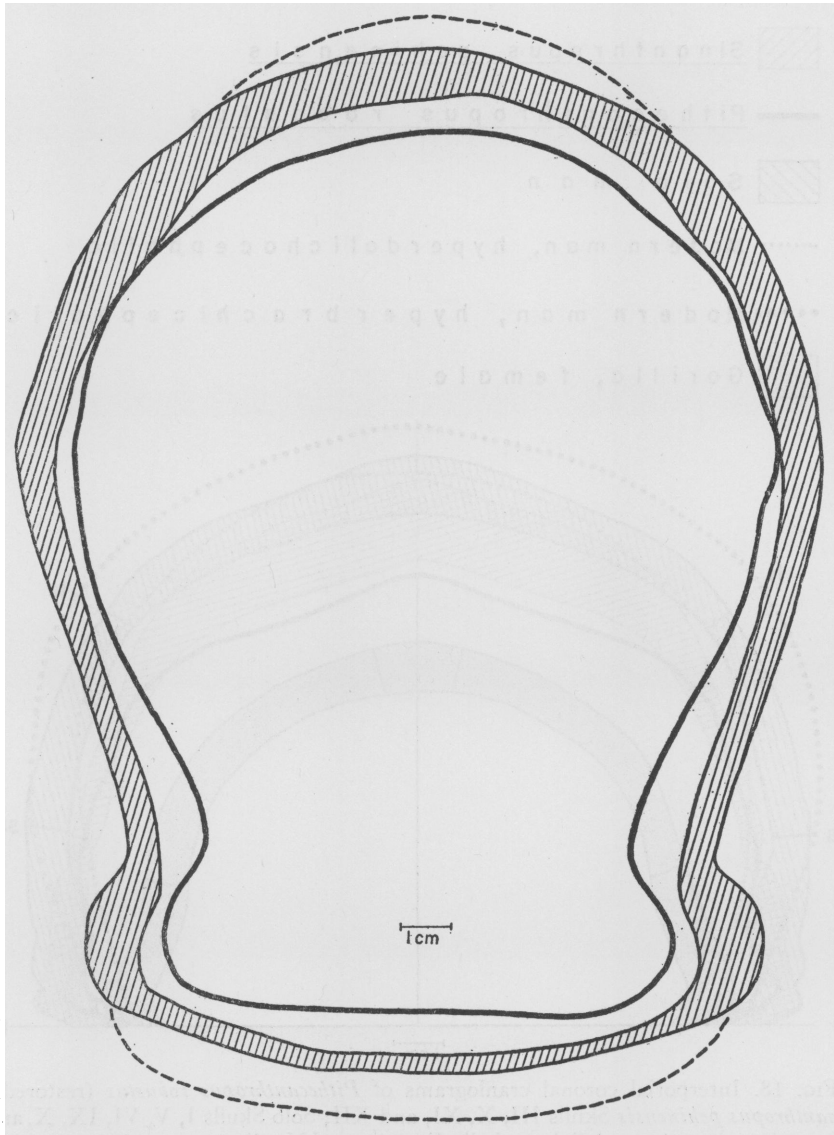


FIG. 19. Horizontal craniograms marking the minimum and maximum limits of the expansion of the braincase of Solo Skulls I, VI, IX, X, and XI (lines bordering the hatched area); Solo Skull V (broken line); and *Pithecanthropus erectus* II (heavy, continuous line).

93 per cent and 69 per cent, respectively; in a male chimpanzee the condyle length is 88 per cent of the foramen length, and breadth is 57 per cent. In orang-utan the rates are 73 and

their longitudinal axes do not parallel the mid-line but are curved, following the contour of the foramen. Their articular facets are turned outward, forming an angle of about 40° with

the horizontal plane. But they are like those of Solo man in that their facets are very slightly curved in the transverse direction, but are markedly so in longitudinal direction. Here we

of the nuchal plane. It is directed upward in Solo man and the anthropoids. The size of the condyles is not dependent upon the size and robustness of the skull, since the condyles

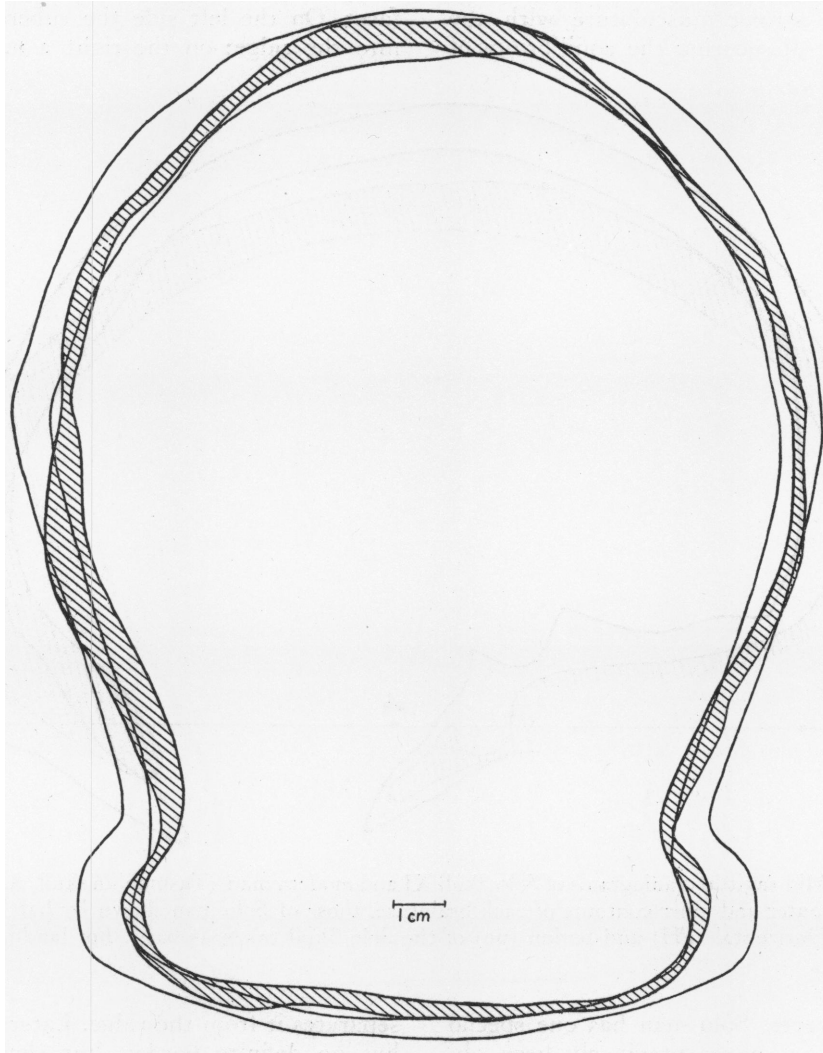


FIG. 20. Horizontal craniograms marking the minimum and maximum limits of the expansion of the braincases in *Sinanthropus pekinensis* Skulls X, XI, and XII (lines bordering the hatched area) and Solo Skulls I, VI, IX, X, and XI (lines bordering the blank area).

have similar conditions to those described above; the posterior part of the facet is bent upward and the anterior part downward.

From all these facts it follows that the longitudinal curvature of the condyles in its posterior parts corresponds to the orientation

are relatively much larger in the anthropoids than in the much heavier Solo skulls. Therefore the size of the condyles must depend on the relation between skull and spine. In erect position the skull is more readily balanced on the top of the spine if the condyles are nearer

the center of the skull base, and the skull will be correspondingly more easily movable.

This consideration seems to contradict the heaviness of the superstructures and the muscular relief of Solo man which indicate the existence of a strong musculature with the special purpose of securing the equilibrium of

In Skull XI, in which the tuberositas is best developed, its anterior end approximates the form of an independent tubercle. This tubercle borders the fossa condyloidea and is completely smooth, resembling an articular facet. On the left side the tubercle continues into the ridge; on the right a narrow groove

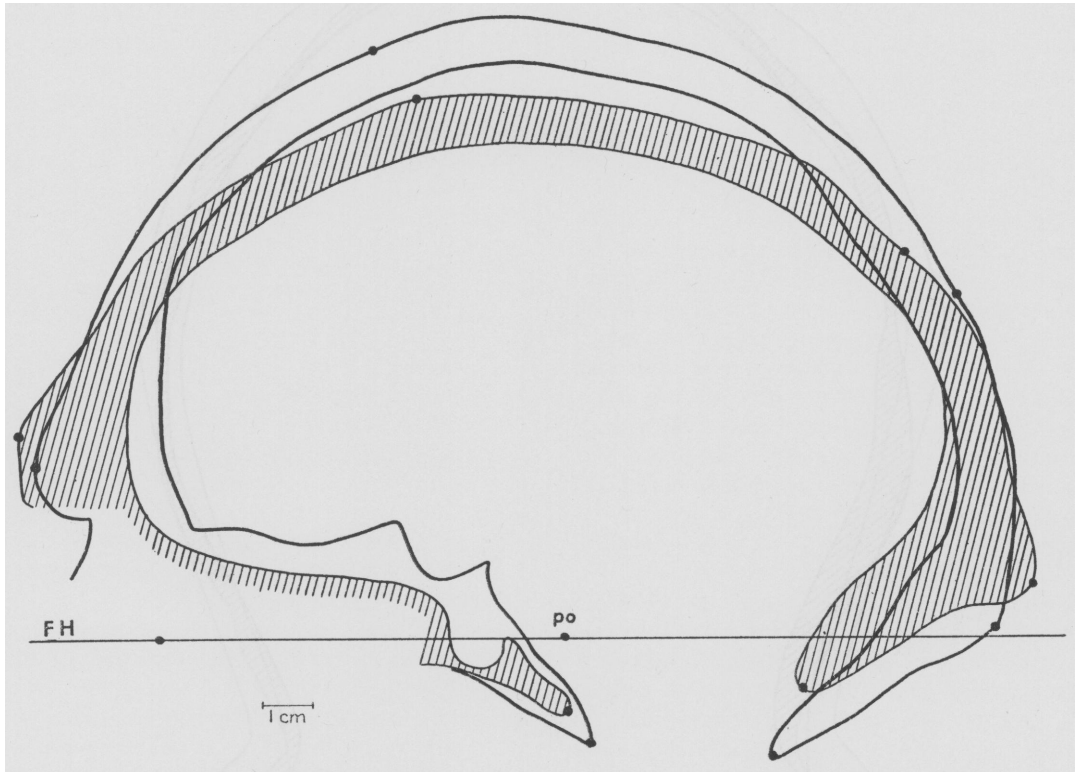


FIG. 21. Mid-sagittal craniograms of Solo Skull XI and modern man (Tasmanian skull, A.M.N.H., V.L. 275); outer and inner contours of each braincase, those of Solo man shown by hatched lines. Frankfort Horizontal (FH) and porion (po) of the Solo Skull taken as basis. For landmarks, see Fig. 4.

the skull. However, Solo man has one special feature which has never previously been observed in early hominids. It may occur there, but as the basilar parts are only occasionally preserved, we had no knowledge of their existence up to that point. In any case, it seems to be missing in the Rhodesian skull. I have called this feature *tuberositas postcondyloidea*. It is a long, rough ridge which has its origin immediately behind the condyle as a high bulge and flattens out and tapers towards the posterior end of the foramen. Actually it represents the elevated margin of the foramen occipitale.

separates it from the ridge. Laterally the ridge has no definite border, but slopes gradually towards a wide depression which, farther laterally, is bounded by the crista occipito-mastoidea.

The tuberositas postcondyloidea is found in Skulls VI and XI on either side and in Skull I where the whole formation is so narrow, smooth, and distinct from its immediate surroundings that Oppenoorth¹ mistook it for a condyle. Only the posterior end of the foramen with its

¹ Oppenoorth, 1932c.

rim is preserved in *Sinanthropus* Skull XII. I noted in the *Sinanthropus* paper, "its rim is not flat but distinctly elevated."¹ But on the right side (the left side of the rim is damaged) I overlooked the end of a well-developed tuberositas postcondyloidea which is still recognizable. This is interesting because in *Pithecanthropus robustus* in this region the whole rim is swollen, but there is no distinct tuberositas.

It is strange that, at least to my knowledge, the structure has never been described in modern man, although it is not rare. It is readily recognizable in Tasmanian and Australian skulls, but it never attains the dimensions and distinctiveness shown in Solo man. Traces of this tuberosity can also be found in European skulls. In these examples the tuberositas appears as an irregular, broad, and, in part, rough margin of the foramen occipitale which usually presents a more or less sharp edge. Occasionally it is paralleled by a second edge around the foramen at a distance of some millimeters. All these structures are obviously vestigial remnants of an originally much more pronounced formation such as appears in Solo man.

In the anthropoids, if the structure has developed at all, it is very small and indistinct. I found it in large gorillas in the form of a somewhat more distinct tubercle immediately at the posterior border of the fossa condyloidea.

As to the significance of the tuberositas postcondyloidea, it is obvious that it cannot have any connection with cervical muscles, because none of them come so close to the occipital foramen. But the capsula articularis, the membrana atlanto-occipitalis posterior, and the connecting ligaments are attached to the region in question. They may have been much more powerful and thicker than in modern man, analogous to the robustness of the whole skull structure, providing additional evidence of this specialization even in places that are otherwise not affected.

The fossa condyloidea differs remarkably in position, form, and extent in Solo Skulls VI and XI. At the right side of Skull VI a small, shallow pit lacking any specific limitations lies behind and lateral to the condyle. A canalis condyloideus is not recognizable. At the left side of the same skull the pit, situated lateral

to the condyle, is small, deeper, and more distinctly demarcated (diameter, 0.8 mm.) and, as on the right side, no canal was found. Both sides of Skull XI have large, deep fossae lateral to the base of the condyle and extending backward from it. The pits are oval; longitudinal diameter of the left pit, 17 mm.; right pit, 20 mm. Near the posterior end of the right pit is a small oval foramen; the left pit contains two such foramina, a medial and a lateral one. The foramina are much smaller than those usually found in modern man. The fossa region in *Pithecanthropus robustus* is broken on both sides, but on the right, lateral to the condyle, there seems to have been a small fossa. As to the Rhodesian man, Pycraft states:

The *fossa condyloidea* is of interest on account of its great depth, and lodges a well-defined *canalis condyloidea*.²

In modern man there is great variability; the fossa is situated behind the condyle, and the canal is present and large, though occasionally the canal is either small or absent. Among the anthropoids the fossa has the same variability as in modern man. It is situated behind the condyle, and usually there are several small foramina, although a single large one may occur.

As I have mentioned above, the angle of the occipital bone between the foramen jugulare and the paramastoid process is of special interest. A distinct but not very pronounced jugular process rises at the left side of Skull VI. The right side of the same skull has no such projection, but the surface forms an irregular depression medial to the foramen stylomastoidium. At the right side of Skull XI this area contains an almost circular pit about 10 mm. in diameter and about 10 mm. deep. Its anterior wall has the appearance of a thin septum between the fossa jugularis and the pit. Its posterior wall is formed, in part, by the broad, thickened end of the crista occipito-mastoidea. A round foramen about 1.5 mm. in diameter occurs near the deepest point of the floor of the pit. At the left side of the skull is a similar structure, differing from that on the right side only in form; it is oval, its greatest diameter (16 mm.) extending in transverse direction. A

¹ Weidenreich, 1943.

² Pycraft, 1928, 5.

small ridge divides the floor into a lateral and medial niche. Like the pit on the right side and in the same position, the medial niche has a small, circular outlet.

This fossa, which I have called fossa postjugularis, is not an accidental structure. It is absent in Skull VI and in Skull I in which this part of the occipital bone is preserved, but is present on the left side of Skull V, the right side of the occipital bone being broken off. The fossa is oval, but larger and deeper than in Skull XI. Its greatest diameter (21 mm.) is in longitudinal and slightly medial-lateral direction. There are two niches in its lateral wall, but no outlet could be found in the floor. In *Pithecanthropus robustus* the whole region is broken off.

I was unable to find any reference in the literature to this fossa or any similar structure in the position of the jugular process in either fossil or modern man, or in anthropoids. If it does occur, it is certainly a rarity in either of these groups. It seems to me significant that the fossa is situated at the outside of the base precisely at the place where, on the cerebral side, the sulcus sigmoideus passes over the rounded, elevated border of the incisura jugularis.

Contrasting with the thickness of all the other bones, the whole area of the fossa is very thin. In the radiographs (Pl. 47) the fossa is recognizable beside the fossa condylea. Its contours are so completely rounded that they give the impression of the pneumatic cells so characteristic of the mastoid region. The outlet of the fossa leads directly into the sulcus sigmoideus. All these conditions and its proximity to the fossa jugularis, from which the fossa postjugularis is separated by a septum, suggest that this may be a pit in which the bulbus jugularis, the origin of the vena jugularis interna, is lodged. In modern man this bulbus is situated in a special compartment of the foramen jugulare which is formed by a depression of the pyramid. Such a depression, though it is much smaller and shallower than in modern man, also exists in Solo Skull XI. Therefore, it is possible that the fossa postjugularis has some relation to the development of a separate jugular bulbus. However, there is also another possibility. The processus jugularis region is the place of origin of the musculus rectus capitis

lateralis. But these points of origin are projections and not depressions, particularly in Solo man where the muscle attachments form very pronounced crests or tuberosities. Depressions are developed only at the superior region of the nuchal plane below the occipital torus, and they are large and relatively shallow, and not small, deep pits like the fossa postjugularis. Therefore its significance remains in doubt.

The corpus of the speno-occipital bone (os basilare), the real center of the base, is preserved in Solo Skulls VI and XI. The length (hormion-basion) in Skull VI is 34.5 mm. and its breadth is 24.5 mm., and 35.2 mm. and 23.2 mm., respectively, in Skull XI. The breadth-length index of Skull VI is 71 and that of Skull XI is 68.8. In modern man the index variation is approximately the same, but the length and breadth of the corpus are, in general, smaller. In the great apes, on the contrary, the index is much smaller, about 55 on the average, which means that the corpus is narrow in relation to its length. Solo man, however, shows one characteristic difference when compared with modern man. The corpus broadens towards the foramen occipitale in both, but in Solo man it widens more and in a special way. A broad, alalike projection, beside the pyramid and in front of the opening of the canalis hypoglossus, forms the medial part of the anterior margin of the foramen jugulare. This also has almost completely disappeared in modern man; there is no lateral projection which deserves mention. However, such a projection seems to be present in the Rhodesian skull. The conditions in the La Chapelle-aux-Saints skull are not clear. The ala exists in the orang-utan, but not in gorilla and chimpanzee. Its disappearance in man is apparently the result of the general reduction of the pyramid, which will be discussed below.

Immediately behind the hormion, 6 to 7 mm., a narrow furrow crosses the corpus. In Skull XI it is an almost straight line. In Skull VI a curved furrow lies on either side in exactly the same position as in Skull XI; the curves meet in the mid-line. These furrows are apparently the remains of the completely ossified synchondrosis speno-occipitalis. Their location in modern man is the same. Behind these furrows in Skull VI and approximately in the center of the corpus, a small, round elevation is barely recognizable. This is obviously the tuberculum

pharyngeum. In almost the same position in Skull XI, exactly at the mid-line, is a small but very distinct foramen. A fine furrow, about 8 mm. long, extends backward from the synchondrosis to this foramen. Its opening on the cerebral side could not be fixed. It is not a canalis cranio-pharyngeus, the occasional persistence of which has been recorded in modern man and chimpanzee. Its location and course do not justify such an interpretation. It must have served as a passage for a blood vessel. Two more of these foramina, one on either side, are present in Skull XI. They are situated farther back and, with the median one, form a fairly regular triangle. Skull VI has none of these openings.

Laterally from each of the two foramina along the edge of the corpus is a distinct, lengthy tubercle: crista muscularis (basio occipitalis). It corresponds to the point of attachment for the musculus rectus capitis anterior. In Skull VI the tubercle is much less distinct. It is not unusual to find a tubercle in the same area in modern man. In both Skull VI and Skull XI, the canalis hypoglossi is a surprisingly wide, oval opening, measuring almost 8 mm. in length.

The cerebral surface of the occipital bone has been made accessible for study in Skulls VI and XI by casting the cranial cavity. The most interesting details revealed in this way are the features of the corpus. The clivus is surprisingly short, that is to say, the distance from klition on the dorsum sellae to basion measures only 20.5 mm. in Skull XI and 28 mm. in Skull VI against 42 mm. in a Tasmanian skull (A.M.N.H., V.L. 275) measured for comparison. This gives the impression that the clivus of Solo man is less steep than that of modern man. This, however, is not true, for in both cases the angle of the clivus between its outer and inner surfaces at the basion is about the same, 30° to 35°. Therefore, it is only its shortness which makes the clivus appear flatter. The region anterior to the dorsum sellae will be described below in connection with the sphenoid bone.

The area immediately surrounding the foramen occipitale in the Solo skull differs from that of modern man in only two features. In Solo man and modern man the foramen is framed by an elevated ring which continues anteriorly into

the two side parts of the clivus and posteriorly into the crista occipitalis interna. In both Solo man and modern man the marginal rings which continue into the clivus are tunneled by the canalis hypoglossus, but in Solo man the tunneled portion is much broader than in modern man. This corresponds to the greater breadth of what has been described above as the alae of the corpus occipitale. The frame around the posterior half of the foramen is also much broader than in modern man. This is also true of the crista occipitalis interna which is over 15 mm. wide above the posterior end of the foramen where it divides into the two legs which encircle the foramen to form the ring.

On the inside of the squama occipitalis the two fossae occipitales superiores and inferiores are separated by the eminentia cruciata and the crista occipitalis interna, respectively. Contrary to the conditions in modern man, the eminentia and the crista are much less prominent. The cristae do not merit a designation as "crests" because they are all broad, rounded elevations, and the sulci of the dura mater, which in modern man are grooved into the crests, are barely developed or completely absent. As in *Sinanthropus*, *Pithecanthropus*, and Neanderthals, the protuberantia occipitalis interna, the crossing point of the four legs of the eminentia cruciata, is situated below the inion, as shown in Table 11. This is in accord-

TABLE 11
DISTANCE BETWEEN INION (CENTER OF THE OCCIPITAL TORUS) AND INTERNAL PROTUBERANCE
(IN MILLIMETERS)

Specimen	Distance
Skull I	
Skull V	32
Skull X	38
Skull VI	26
Skull XI	21
<i>Pithecanthropus</i> , adult average	35.21
<i>Pithecanthropus</i> , II	25 ^a
Neanderthal, 10-24, average	17.2

^a Not 15 as given in my paper.

ance with the size of the fossae occipitales inferiores which is relatively small. However, more characteristic than their size is their

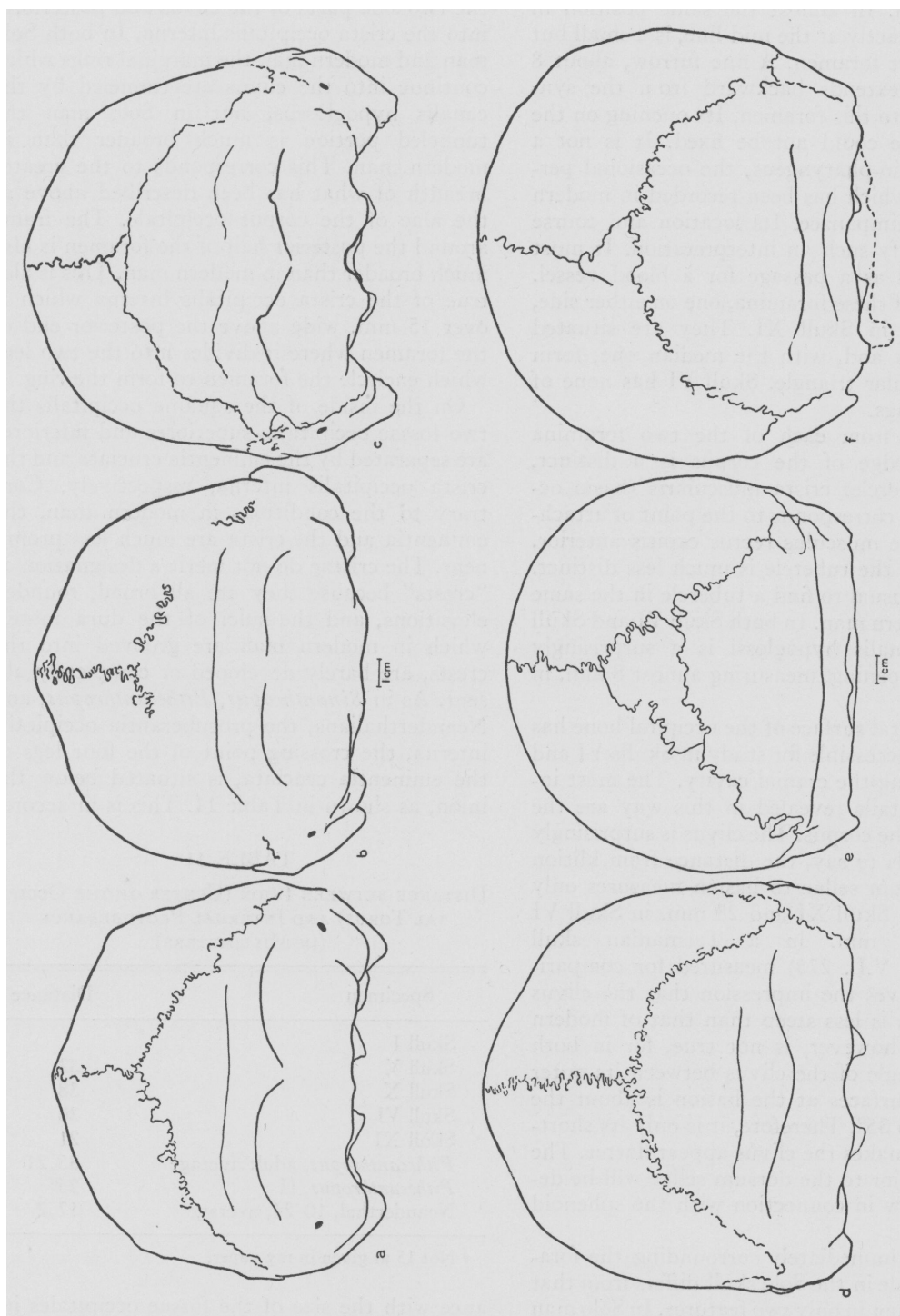


FIG. 22. Comparative occipital views (norma occipitalis). a. *Pithecanthropus robustus*, new reconstruction. b. *Sinanthropus pekinensis* Skull XI. c. Solo Skull XI. d. Rhodesian skull, after Pycraft. e. Saccopastore Skull I, after S. Sergi. f. Skull of La Chapelle-aux-Saints.

shallowness. Although the degree of elevation and the breadth of the crista occipitalis contribute in large measure to the impression of shallowness of the fossae, the cavity itself is actually much less pronounced than in modern man. The fossae occipitales superiores are also small and shallow. The conditions in *Sinanthropus* are very similar, differing only in the development of the eminentia cruciata and their legs which approach the condition found in modern man, particularly in the development of the sulcus transversus and sagittalis. *Sinanthropus* resembles modern man more closely than Solo man in this regard. Of special interest are the conditions in *Pithecanthropus*. In *Pithecanthropus erectus* Skull II, very little of the region under consideration is preserved: the lower sagittal leg of eminentia cruciata resembles that of Solo man, the superior leg is in the form of a very sharp crest, and the transverse legs are barely indicated. This is the same in *Pithecanthropus erectus*. There is no difference in the appearance of the eminentia cruciata in *Pithecanthropus erectus* and Solo man. But the fossae occipitales inferiores are without doubt deeper in *Pithecanthropus robustus* than in *Pithecanthropus erectus* and Solo man. All this shows a definite degree of variability in this whole hominid group, but certain important differences between this group and modern man remain. These are the low position of the protuberantia interna in relation to the position of the inion and the decrease in height and greater breadth of the legs of the cruciate eminence and the relative shallowness of the inferior occipital fossae. Little is known about these features in the Neanderthals. It would be interesting to know more about them, especially with regard to the Rhodesian and Gibraltar skulls. The mid-sagittal diagrams of the Gibraltar and Rhodesian skulls suggest a clivus occipitalis less steep than that in man, but this should be checked on the specimens. In the great apes the crests connected with the cruciate eminences are as broad and low as they are in Solo man. But the sulci are, in general, well developed.

TEMPORAL BONE

Since very few differences are revealed by a comparison of the temporal bone of *Sinanthropus* and Solo man, reference is made to the description of this bone in my paper on the

skull of *Sinanthropus*.¹ Through *Sinanthropus* we are acquainted with only the posterior and lateral part of the pyramid, since its anterior and medial sections were not preserved in any of these skulls. Solo man, especially Skulls VI and XI in which all the parts missing in *Sinanthropus* are intact, offers an excellent opportunity to complete our knowledge of the previously missing portions. It was pleasant to find that my hypotheses concerning the missing parts, based on the fragmentary conditions of the *Sinanthropus* skulls, have proved correct. In addition, the new materials demonstrate the morphological unity and more primitive status of all the representatives of the Archanthropine group as compared with all the known Neanderthals.

SQUAMOUS PORTION

The squamous portion has the characteristic *Sinanthropus* form. When the root of the zygomatic process and the crista supramastoidea, which represents its continuation backward to the mastoid portion, is taken as the base, the squama is almost triangular; the margo parietalis (sutura squamosa) is an oblique, almost straight line extending forward and upward towards the pterion where it meets the sphenosquamosal suture at a right angle. The sphenosquamosal suture runs down vertically to the origin of the squamosal process (Pls. 33, 34).

This fundamental triangular form of the squama is typical of the anthropoids, the only difference being that in the latter the base of the triangle is elongated and the height is decreased. The form of the squama in Solo man, with the exception of that of Skull VI, is the same as it is in *Sinanthropus*. In Skull VI the end of the crista supramastoidea is directed more or less horizontally but does not, as in the others, bend upward to meet the horizontal portion of the squamosal suture, thus producing a change from triangular to an approximately rectangular form. In modern man the straight line of the squamosal suture has been transformed into a high curve in conformity with the increase in height of the whole braincase. The Neanderthals have the modern human pattern.

In my paper on *Sinanthropus*, I have given

¹ Weidenreich, 1943, 43 et seq.

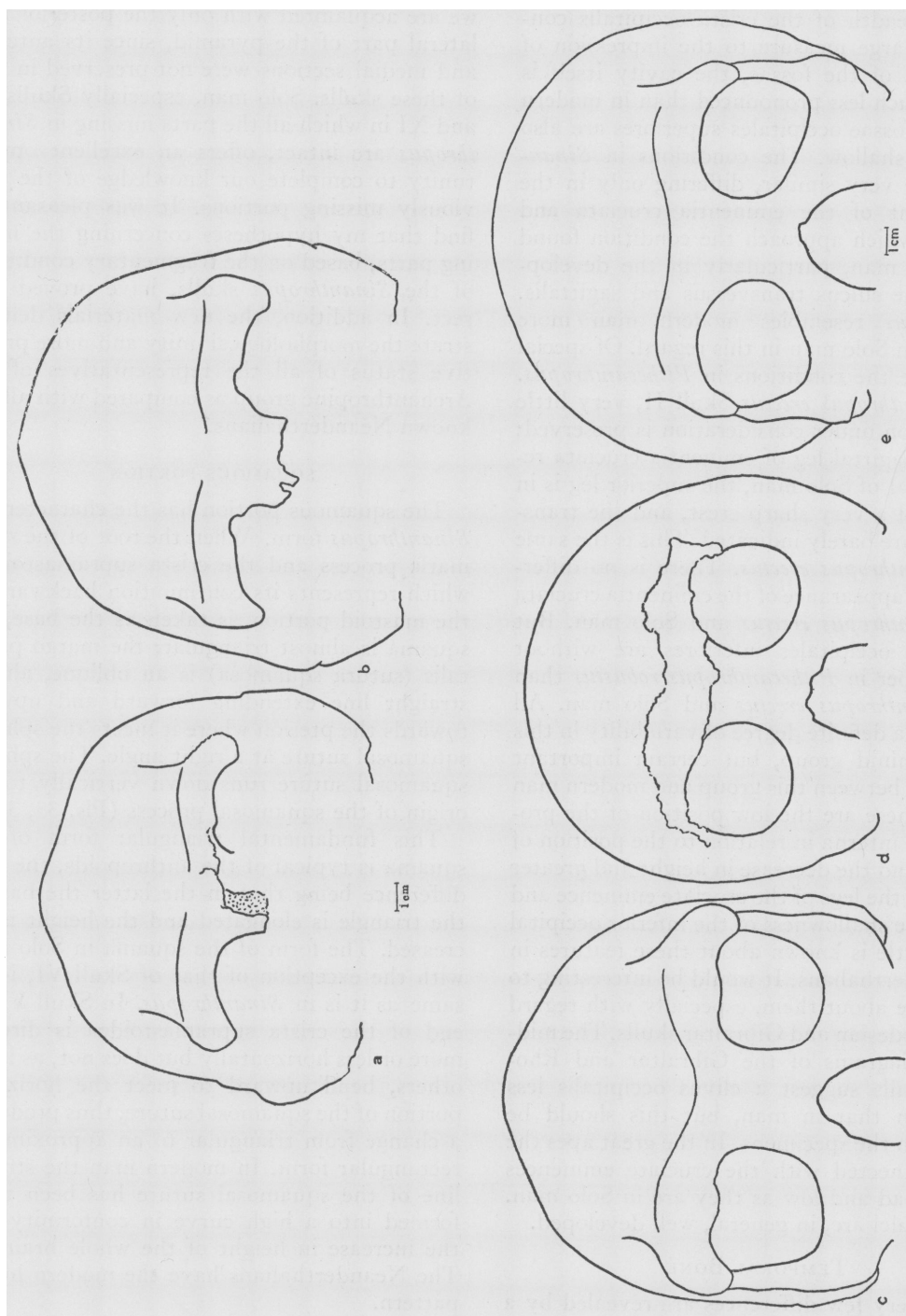


FIG. 23. Comparative frontal views (norma frontalis). a. *Sinanthropus pekinensis* Skull XI. b. Solo Skull XI. c. Rhodesian skull. d. Saccopastore Skull I, after S. Sergi. e. Skull of La Chapelle-aux-Saints.

the measurements (length and height) of the squamosal triangle in Table 9.¹ The average length of measurable temporal bones is 69.6 mm., the average height 34.5 mm., and the average length-height index 49.7. In the five measurable temporal bones of Solo man, the average length is 73 mm., the average height 46.9 mm., and the average index 46.9. In modern man the average length-height index is 65.2.²

The line along which the zygomatic process is fixed at the squama and its direct continuation, the supramastoid crest, does not run parallel to

The zygomatic process of the temporal bone is preserved in Skull V (left side), Skull X (left side), and Skull XI (right side). In all these skulls the process juts out from the temporal squama in a widely arched, forward curve. The width of the "sulcus processus zygomatici" at the point where the zygomatic arch becomes free measures about 15 to 20 mm. In modern man it is usually narrower, although in phenozygomatic skulls the width may be the same as in the Solo skulls.

The articular tubercle and the fossa mandibularis are excellently preserved for their entire

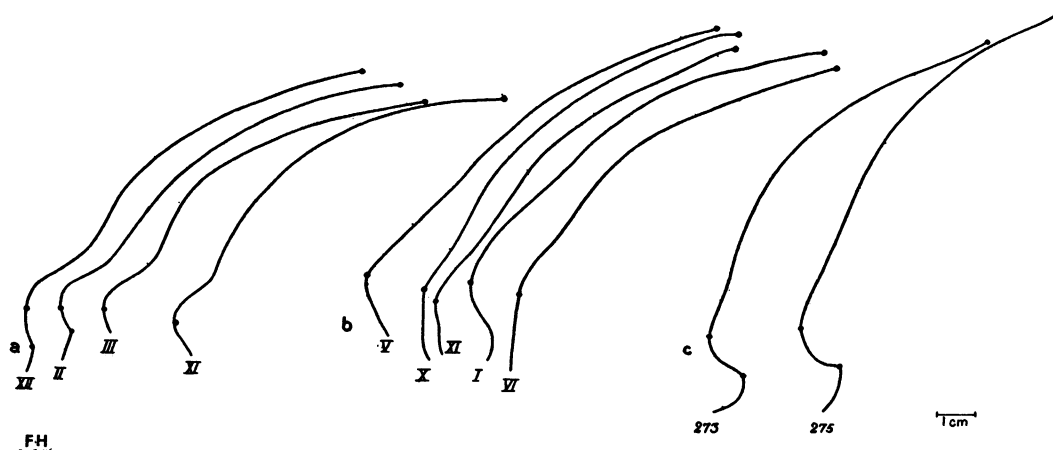


FIG. 24. Incline of the frontal bone, with regard to the Frankfort Horizontal, as shown in mid-sagittal craniograms. a. *Sinanthropus pekinensis*. b. Solo skulls. c. Modern man (Tasmanian).

the Frankfort Horizontal its entire length as it does in most modern human skulls, but ascends backward from its beginning. The line forms (with the Frankfort Horizontal) an angle of about 25° , which is slightly smaller than in *Sinanthropus*. In the Neanderthals the root of the zygomatic process is parallel to the Frankfort Horizontal, but the end of the supramastoid crest bends slightly upward. This condition is also present in modern man if a distinct supramastoid crest has developed. In the anthropoids, where the supramastoid crest continues into the nuchal crest, the ascent of the whole line is a characteristic feature. As in *Sinanthropus*, the supramastoid crest ends abruptly at the squamosal suture, and there is no connection with the occipital torus or with the torus angularis of the parietal bone.

extension in Solo Skull XI (right side); in other Solo skulls the region is partly damaged. In most of the skulls the lateral portion, together with the root of the zygomatic process, is broken off. But in the remainder they did not differ markedly from the features revealed in Skull XI. Compared with *Sinanthropus*, the pattern in Solo man is identical in principle, but the tubercle and the fossa behind it are distinctly larger in Solo man. For a detailed description, reference is made to my paper on *Sinanthropus*³ (little has to be added). The articular facet, which carried a cartilaginous coat, is more distinct than in *Sinanthropus*, although the "tubercle" as a whole does not rise much above the "planum" glenoidale. Regarding the fossa mandibularis itself, Davidson Black⁴ stated that it is "deeply excavated and

¹ Weidenreich, 1943, 44.

² Cf. Schultz, 1915.

³ Weidenreich, 1943.

⁴ Black, 1931.

essentially hominid in form." This is also certainly true for Solo man. But in sagittal direction the fossa is much wider in modern man than in Solo man or *Sinanthropus*. In Table 10 of my paper on *Sinanthropus*,¹ I have given the three dimensions (length, breadth, and depth)

of the anterior wall of the fossae) is 31 mm.; the depth (the plane in which the length is taken as base) is 16.5 mm. In the Tasmanian skull (A.M.N.H., V. L. 275) the corresponding measurements are 28, 27, and 12 mm. The length-depth index is 46 in Solo man and 43 in the Tas-

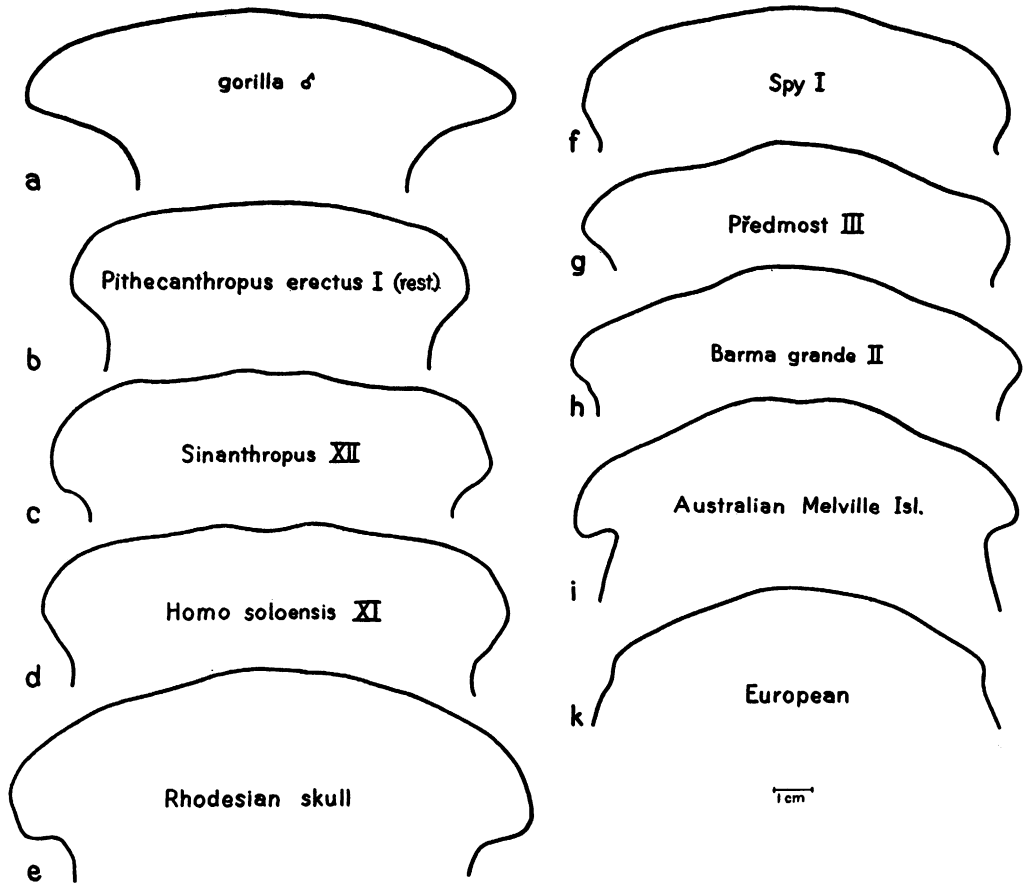


FIG. 25. The gradual disintegration of the supraorbital tori in the course of human evolution, as it appears in vertical view.

of the fossa. The difficulty is that no precisely corresponding landmarks are available for comparison of the different hominid groups and anthropoids, unless all the structures bordering the fossa are preserved. Such a comparison is possible in very few specimens. In Solo Skull XI (right side) the length (middle of the anterior end of the articular facet to the top of the spina petrosa of the tympanic plate) is 36 mm.; the breadth (the greatest medial-lateral extension

of the fossa) is 31 mm.; the depth (the plane in which the length is taken as base) is 16.5 mm. In the Tasmanian skull (A.M.N.H., V. L. 275) the corresponding measurements are 28, 27, and 12 mm. The length-depth index is 46 in Solo man and 43 in the Tas-

It is, however, impossible to describe the

¹ Weidenreich, 1943, 46.

² Weidenreich, 1943, 46.

most characteristic features of this area in terms of measurements. A sagittal craniogram, from the ultimate anterior end of the articular facet through the deepest part of the fossa to the highest point of the petrous crest and behind it through the foramen stylo-mastoideum and along the medial surface of the mastoid process (Fig. 26a), shows better than any measurement the sectional view of the entire region in question, particularly when compared with the corresponding diagram of modern man (Fig. 26d). If we define the fossa mandibularis as the entire indentation between the deepest point of the articular tubercle (anterior wall) and the deepest point of the tympanic plate (posterior wall), it is very deep and very narrow in sagittal direction in Solo man as compared with modern man.

As I have stated in my paper on *Sinanthropus*, depth and narrowness of the fossa are completely irrelevant as the bases for drawing conclusions regarding the mechanism of the mandibular joint and eventual differences in hominids and anthropoids. The meniscus, but never the capitulum, of the condyle is lodged in the deeper parts of the fossa. Any difference in the depth of the fossa can be, and is, compensated for by varying thickness of the meniscus. In reality, when the mouth is closed the capitulum of the condyle rests on the upward slope of the articular tubercle itself and, when the mouth is open, glides forward over the apex of the tubercle. As in *Sinanthropus*, the characteristic feature of the mandibular articulation of Solo man is the form not of the fossa but of the tubercle. In both sagittal and transverse direction (cf. the measurements above), it is much larger than in modern man and allows a much wider range of movement.

The anterior wall of the fossa is more concave than is usual in modern man; its backward-facing medial and lateral parts, the entoglenoidal and ectoglenoidal processes, are well developed, much more so than in modern man. The entoglenoid process is, however, not formed by the squama temporalis alone as in *Sinanthropus*, but either the spina jugularis of the sphenoid or both structures, squama and sphenoid together, contribute to its formation. The ectoglenoidal process is much less distinct than the entoglenoidal. The low ridge, which turns medially from the root of the jugular process in

Sinanthropus and separates the lateral half of the mandibular fossa from the vestibule to the meatus acusticus externus, is almost completely missing. I have described this ridge as the vestigial equivalent of a postglenoidal process. In Solo man this structure is reduced to a short, thin line. It cannot form the posterior wall of

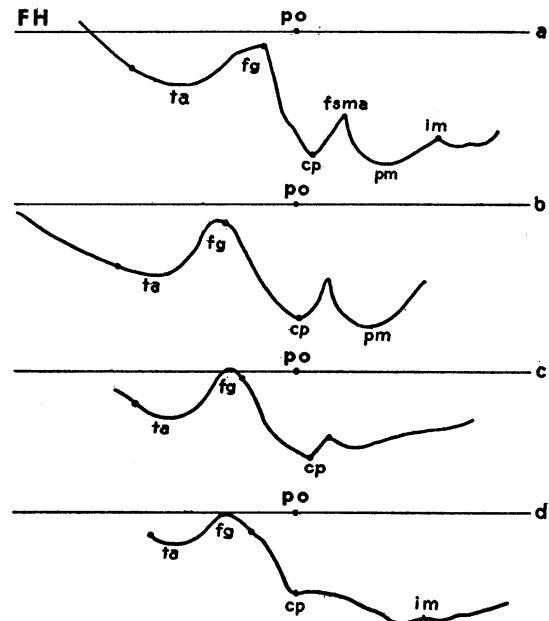


FIG. 26. Para-sagittal craniograms along the base of the squamosal, tympanic, and mastoid bones (fossa mandibularis and adjacent parts). a. Solo Skull XI, right side. b. *Pithecanthropus robustus*, right side. c. *Sinanthropus pekinensis* XI, left side. d. Modern man, Tasmanian skull (A.M.N.H., V.L. 275), right side. Abbreviations: cp, crista petrosa; fg, fissura Glaseri; FH, Frankfort Horizontal; fsma, foramen stylo-mastoideum; im, incisura mastoidea; pm, processus mastoideus; po, porion; ta, tuberculum articulare.

the fossa, not only because it is much too small, but, above all, because it is a structure of the anterior and not of the posterior wall of the fossa. This reveals another peculiarity of the mandibular fossa of Solo man. The deepest point of the fossa in modern man and in *Sinanthropus* is situated farther forward than in Solo man, and the floor of the fossa ascends towards the posterior wall before it reaches the Glaserian fissure. However, in Solo man this fissure runs along the very floor of the fossa; the

wall ascends in front of and behind it (cf. Fig. 26). The posterior wall is formed for its full extent solely by the tympanic plate. In modern man where a postglenoidal process is developed, it never reaches farther than the deepest portion of the fossa which lodges the meniscus, nor does it form a posterior bony wall for the mandibular joint as this process does in anthropoids. In modern man, as in Solo man, the tympanic plate provides the posterior wall of the fossa. It is of greatest interest that the mandibular fossa of *Pithecanthropus robustus* (Fig. 26b) generally has exactly the same form as that of Solo man (Fig. 26a). There are, however, some differences. The tubercle is shorter and higher in *Pithecanthropus*. A postglenoidal process separates the most lateral part of the fossa from the vestibulum of the ear entrance, but the tympanic plate is almost perpendicular and forms the main part of the posterior wall of the fossa.

One peculiarity of the mandibular fossa of modern man is a distinct medial wall formed by the entoglenoidal process in front of the Glaserian fissure, and by the tympanic plate behind the fissure. However, since the fossa is "open," no such distinct border is found at the lateral side. In early man, where the fossa is deep and the anterior and posterior walls are steep, this difference is more conspicuous. The transverse axis of the anterior and posterior walls meet medially at an angle of between 50° and 60° (Tasmanian skull, A.M.N.H., V. L. 275, 50°). In Solo Skull XI this angle is only about 15°. In *Sinanthropus* Skull III the angle is about the same as in Solo man. In *Pithecanthropus robustus* it is about 20°; in Rhodesian man it is also about 20°.

The transverse axis of the anterior wall represents the transverse axis of the fossa itself. It is not parallel to the transverse porion axis, but forms an acute angle of about 30° in modern man and approximately 20° in Solo man. This angle corresponds to the orientation of the transverse axis of the capitulum of the mandibular condyle which, in hominids and anthropoids, faces obliquely backward, laterally and medially.

The widening of the fossa mandibularis angle from a range of 15° to 20° in Solo man to 50° to 60° in modern man results from a change in the

orientation of the transverse axis of the tympanic plate, as will be shown below.

As to the topographic orientation of the mandibular joint in relation to the braincase and brain cavity, in my paper on *Sinanthropus* I stated that in *Sinanthropus* the center of the fossa is on the inside of the braincase close to the cerebral surface of the wall. In Solo man the orientation of the mandibular fossa does not differ essentially from that of *Sinanthropus*. Its position in *Pithecanthropus* Skull II and in *Pithecanthropus robustus* is also the same. I recall that in modern man the center of the fossa is distinctly inside the wall; in the chimpanzee it is just below the wall, and in adult male gorillas and orang-utan outside the braincase on the jugular process. Broom's illustration of *Paranthropus robustus*¹ and the cast at my disposal admit no doubt that *Pithecanthropus* shows the same conditions as adult modern chimpanzee and, I may add, juvenile gorillas. The extreme lateral position of the fossa in adult gorillas and orang-utan is certainly caused by the enormous development of the jaws coincidentally with the completion of the permanent dentition. Therefore it is not the expansion of the brain and braincase which brought the fossa mandibularis region on the base of the skull within the compass of the cranial cavity, but the enlargement of the total masticatory apparatus which produced the lateral expansion of the whole joint complex at the base and the shifting of the fossa on the jugular process.

The interior surface of the Solo squama does not differ much from that of *Sinanthropus*, except for the greater width of the floor of the middle fossa cerebri. This will be discussed later.

TYMPANIC PLATE

My remarks about the tympanic plate of *Sinanthropus* also hold true for Solo man. As in *Sinanthropus*, the tympanic plate differs from that of modern man in position, form, and thickness.

The crista zygomatica and supramastoidea form an overhanging roof above the entrance to the porus acusticus externus. This "tegmen vestibuli" varies in breadth between 10 and 15 mm., depending on the development of the

¹ Broom and Schepers, 1946, Fig. 85, Pl. 8.

overhanging cristae. The tegmen is apparently slightly smaller in Solo man than in *Sinanthropus* because the projection of the crista zygomatica decreases immediately above the vestibulum and increases again behind it, towards the crista supramastoidea. This is not the situation in *Sinanthropus*.

A characteristic feature of the vestibulum of Solo man is the presence of a typical "spina suprameatum" near the mastoid. It is most obvious on either side of Skulls VI and XI and in Skull IX on the left side. It is not distinct in Skulls V and X and is missing on the right side of Skull IX. In Skull VI the spine is a small, low tubercle. In all other skulls it appears, exactly as in modern man, in the form of a narrow cleft about 7 mm. long in sagittal direction, with a small but distinct crest marking its lower border. Neither *Sinanthropus* nor *Pithecanthropus* has a typical spine. Only *Pithecanthropus robustus* has on the right side a pin-head-like elevation which may be its equivalent. A typical spine is present in Neanderthals. In this regard, Solo man resembles the Neanderthals and differs from *Sinanthropus* and *Pithecanthropus*. As to its significance, I can now state that it is a relic of the original tympanic ring which is more developed at the side of the mastoid, reaching farther upward and forward. When in man and in anthropoids the ring recedes from this region in the course of ontogenetic development, a furrow remains, adhering at the posterior part of the roof of the vestibulum. This is the origin of the spina suprameatum. I do not know why it adheres here and not in the earliest hominid stages.

Furthermore, Solo man resembles *Sinanthropus* in the position of the tympanic plate. In Solo man the plate is oriented in a horizontal plane; it is convex and covers the whole petrous portion. In modern man the plate has a vertical position, as though it had glided down into the mandibular fossa. Its originally posterior margin faces upward and appears as the crista petrosa. Consequently, the part of the petrous portion adjacent to the mastoid has been exposed. The face of the plate, which originally faced downward in the correct position of the skull, now faces forward and forms the posterior wall of the mandibular fossa. In Solo man, as in *Sinanthropus*, the plate is vertical but on the

whole forms a forward convex arc. The lower part is bent backward and terminates in a very thick crista petrosa. Behind the crista, in the cleft between the crista and the mastoid, the petrous portion is exposed, but it is only represented by the foramen stylo-mastoideum and the sulcus processus styloideus (see below).

The lateral margin of the tympanic plate forms the entrance of the meatus acusticus externus, but it is restricted to the side walls and the floor, the roof being formed by the squamous portion. The anterior wall ascends much higher than the posterior wall. Both walls are very thick, much thicker than in modern man. The rim is thickest at the floor whence the crista petrosa arises, so that in lateral aspect it appears as a broad triangle. This causes the meatus to appear vertically elliptical, although the aperture itself is almost circular. (For the measurements see Table 12.)

Solo man does not differ essentially from *Sinanthropus* in the form of the aperture, but a comparison with modern man does reveal a difference. In Solo man the aperture is much wider than in modern man, and its frame is on the whole much thicker. In some individuals and races of modern man, as in the Eskimo, the frame, particularly around the floor of the aperture, is extraordinarily thick (ear exostoses). These exostoses are probably the remainder of the original thick frame which has been greatly reduced elsewhere. The greatest reduction of the tympanic plate in recent man is at the center of the posterior wall of the mandibular fossa. This reduction continued until the plate became perforated (Huschke's foramen). Such a foramen is found in about 22 per cent of American Indians and up to 40 per cent in certain Japanese groups.

It is interesting that *Pithecanthropus robustus* has a vertically elliptical aperture. A relatively narrow vertical slit on the right side (see Table 12) may result from a compression of the bone in sagittal direction. On the left side, which does not seem to have been subjected to a similar post-mortem exterior pressure, the aperture is also vertically elliptical. In *Pithecanthropus erectus* (Skull II), however, the aperture is almost circular. All this proves that the form of the aperture is very variable in early hominids, as is also apparent in modern man and anthro-

poids. In one of two chimpanzee skulls I have before me (A.M.N.H. L10276), the aperture on both sides is a narrow slit, 2 mm. by 12 mm.; in the other (A.M.N.H. L270) it is circular, 6 mm. in diameter. Therefore, the form of the aperture cannot be used as a criterion for judging whether or not a given hominid is primitive.

Pithecanthropus robustus holds a surprise in possessing still another peculiarity. The frame of the aperture is relatively thin. The rim of the anterior wall is no thicker than 1.5 mm., compared with 3.5 mm. in Solo man. But at the

split in *Sinanthropus* Skull III is not characteristic of *Sinanthropus* in general, since its occurrence is confined to one skull, and it does not occur in Solo man. It cannot, therefore, be employed as a diagnostic basis for classification as Dubois used it.

The inferior margin of the tympanic plate, the crista petrosa, is much more robust in Solo man than in modern man. Near its medial end it swells to a large, blunt, almost semicircular elevation (spina petrosa) which surrounds an indentation at the posterior side of the plate. This indentation marks the upper end of a deep groove which passes downward vertically and terminates in a pit resembling a foramen. The whole formation corresponds to the "vagina processus styloidei" and the "lamina vagina" of modern man from which that of Solo man differs in two essential features: it is much thicker and coarser, and it does not embrace a styloid process. This process is absent and is replaced by a sulcus that leads to a pit. I will discuss this below. Beyond the petrous spine the margin of the plate runs obliquely forward. Where it meets the spina angularis of the sphenoid, it expands again to form a distinct projection which I named "processus supratubarius" in my paper on *Sinanthropus*. Below this process is the entrance to the canalis musculotubarius. Viewed from the basilar side, as shown in Skull XI and in Skull VI (left side), the entrance to the canal is covered by two projections: a posterior medial and an anterior-lateral projection. The former belongs to the tympanic plate; the latter is the spina angularis. Both processes are in contact. Such a contact is not present in all the specimens; it depends on the development of both formations. I called the tympanic process "supratubarius"; the topographically correct name should be "infratubarius" because it projects below the entrance, not above it. In Solo man the process is much more pronounced and distinct than in *Sinanthropus*, but in *Pithecanthropus robustus* (right side) it far exceeds both Solo man and *Sinanthropus* in size. It is a large, cone-like projection rising from a distinct broad base about 14 mm. in transverse direction. The process had obviously been pointed, but the tip is broken off, exposing a pneumatic cell inside the cone. The process points medially and downward. Above it a large and deep pit leads laterally and

TABLE 12

DIAMETER OF THE APERTURA MEATUS ACUSTICI
EXTERNI (IN MILLIMETERS)

Specimen	Length	Height	General Impression of the Form
Skull I			
Skull V, left	10	12	Round
Skull VI, left	8	13.5	Vertically elliptic
Skull VI, right	9	9.5	Round
Skull IX, right	8.5	9.0	Round
Skull X	8.5	10?	Round
Skull XI, right	11.0	11.5	Round
Skull XI, left	9.5	11.0	Round
<i>Pithecanthropus robustus</i>			
Right	7.0	21.0	Vertically elliptic
Left	8.0	11.0	Vertically elliptic
<i>Pithecanthropus II</i>			
Right	9.0	10.0	Round
Left	9.0	9.0	Round

floor the frame is much thicker, measuring almost 9 mm., because the thick petrous crest extends laterally to the very margin of the aperture and fuses with it.

In some cases, the border at the floor of the meatus has a broad, shallow indentation. The same type of indentation occurs in *Sinanthropus* Skull XI, but in Solo man there is no indication of a penetrating cleft separating the border of the tympanic plate and the plate itself into two lips, as described by Davidson Black for *Sinanthropus* Skull III. This indentation is so slight and accidental that it does not justify the importance attached to it by Dubois,¹ for this

¹ Dubois, 1936, 1940.

upward into the interior of the pyramid. The spina angularis of the sphenoid limits this pit laterally. It is not in contact with the process of the tympanic plate but is separated from it by a slit which continues laterally into the mandibular fossa.

The process in question is found on every adult male gorilla in the form of a sharply pointed cone rising from a large base to about 10 mm. in diameter and 14 mm. or more in height. It is pneumaticized in all cases. Laterally the process leans against the big entoglenoid process of the mandibular fossa. Both formations are fused at the base. Above the tympanic process a wide, deep pit leads into a narrow canal, the opening of the Eustachian tube. In orang-utan and chimpanzee the process is much smaller, having the appearance of a styloid process, with which it should not be confused. In modern man and Neanderthals the "erosion" and reduction that characterize the whole base of the pyramid and the tympanic plate have left little of the process but at best a small, short, thin spine to which attention has never been directed. It is neither described nor illustrated in any anatomical text book.

Van der Klaauw described its occurrence in mammals. According to this author, the process is on the fore end of the auditory bulla and forms the prolongation of the bony Eustachian tube. It should not be confused with the styloid process which it resembles; consequently, Van der Klaauw called it "processus styloformis." It is very variable in the primates—sometimes very distinct, sometimes insignificant.

In the Hylobatidae and Anthropomorphae the styloform process is very distinct. In *Hylobates lar* it is blunt and thick; it is best developed in *Anthropopithecus* [chimpanzee] and *Gorilla*.¹

I had an opportunity to dissect this region in a West African gorilla (A.M.N.H., C. A. No. 1453), and I found that a large muscle bundle which is a portion of the musculus tensor veli palatini takes its origin from the process.

I have dwelt on the description of this process because it is evidently a relic of a very primitive feature in primates, although it varies in its development. In gorilla it is so large that it contains pneumatic cells. It is the most conspicuous

structure at the base of the temporal bone in *Pithecanthropus robustus*. It is a large cone and has even maintained pneumatization. Although reduced in Solo man and *Sinanthropus*, it is still readily recognizable as a characteristic formation. In Neanderthals and modern man it has disappeared so completely that without other evidence no one would suggest that one of the tiny spines that form the base of the normal pyramid and resemble a pathological erosion was, in the earlier stages of human evolution, a conspicuous feature matched only in the male gorilla.

PETROUS PORTION

The lateral part of the inferior surface of the petrous portion of the Solo skulls is covered by the tympanic plate. As described above, the plate extends in the sagittal direction almost to the mastoid process. Between the tympanic plate and the mastoid there remains only a small triangle which belongs to the petrous portion. The greater part of the triangle is occupied by the foramen stylo-mastoideum. The same arrangement is found in *Sinanthropus*. The plate is in a horizontal plane. Medial to the foramen stylo-mastoideum are the foramen and sulcus processus styloidei, but there is no processus styloideus. This process is also absent in *Sinanthropus*. Since I discussed the whole styloid structure in my paper on *Sinanthropus*, it is unnecessary to repeat it here. Solo man and *Sinanthropus* do not differ from each other in these features, but they do differ from the Neanderthals and from the great apes which have a styloid process. In the latter the plate covers the petrous portion to the same extent as in *Sinanthropus* and Solo man. But there is a characteristic difference in the position of the foramen stylo-mastoideum. While in *Sinanthropus* and Solo man the foramen is near the medial surface of the mastoid process, in anthropoids its position is much more medial. Furthermore, the foramen processus styloidei is much more distinct, and a short sulcus is barely indicated. In modern man the tympanic plate is in a vertical position; in the space behind it and the mastoid process is the foramen stylo-mastoideum, surrounded by a small porous area which represents the exposed petrous bone. Medial to the foramen is the styloid process emerging from the foramen processus

¹ Van der Klaauw, 1931, 136.

styloidei and leaning against the posterior surface of the erect tympanic plate.

The apical portion of the pyramid that emerges beneath the tympanic plate reaches forward to the sphenoid. The apex is in contact with the root of the pterygoid process and its lateral side with the ala magna of the sphenoid. A cleft between it and the spheno-occipital corpus is found only at the medial side. The depth of the cleft corresponds in part to the sulcus of the cerebral side in which the carotid artery lodges. Except for this cleft, there is no wide hole around the apex, no indication of a foramen lacerum such as is typical of modern man. The pyramid has developed two marked crests which converge towards the apex. The surface between these crests has a slight longitudinal striation.

In this respect the same conditions are found in Solo man as in the anthropoids. The apical portions completely fill the space between the spheno-occipital corpus at the median side and the alar-squamosal structures at the lateral side. The carotid cleft, too, is filled in the great apes.

I first called attention to another important feature in 1932. The axis of the base of the tympano-petrous portion in *Sinanthropus* is not a straight line, as is common in modern man, but forms an angle, the lateral part (tympanic plate) running in a directly transverse direction and the apical portion of the pyramid passing forward and medially. The angle of the two axes is about 140° in *Sinanthropus* Skull III, in which it can be measured with some accuracy. In Solo man the angle is 130° in Skull XI (right side) and 120° in Skull VI (right side); it is 135° in Skull XI (left side) and 125° in Skull VI (left side). Its range is between 120° and 135° . In anthropoids the angle approaches the lower limit (120°). In modern man the lower and upper limits of angle are from 150° to 180° . In all these cases the apex of the angles lies exactly at the spina petrosa, the entrance to the carotid foramen, and the base of the processus infratubarius, the processus itself forming a part of the angle. I stated above that the anterior and posterior walls of the mandibular fossa form an angle. The apex of this laterally open angle lies at the point where this process (posterior wall) and the spina angularis (anterior wall) meet.

The angle measures 15° in Solo man as opposed to 50° to 60° in modern man. The angle of the tympanic-pyramid axis ranges from 120° to 130° (average 125°) in Solo man and from 150° to 180° (average 165°) in modern man, a difference in averages of 40° . Since the anterior wall of the mandibular fossa remains unaltered in Solo man, *Sinanthropus*, and modern man, the widening of the medial angle of the mandibular fossa in modern man signifies that the tympanic portion has retreated backward and to a degree that accounts for the increase in the angle of the tympano-petrous axis. It is interesting and significant to note that this change is not the result of an actual backward shift of the tympanic portion, since the distance between the articular tubercle and the mastoid is no greater in modern man than in Solo man. In Solo man Skull XI (right side) this distance is exactly 44 mm.; it is only 34 mm. in the Tasmanian skull (A.M.N.H., V.L. 275, right side). Therefore the widening of the lateral angle results from the shrinkage of the tympanic plate in a sagittal direction. It measures 19.5 mm. in the Solo skull but only 14.0 mm. in Tasmanian and Rhodesian skulls. The reasons for this shortening are: first, the change to a vertical position; second, a diminution of the width of the meatus acusticus; and, third, the reduction of the thickness of the whole tympanic plate. I have shown in my paper on the *Sinanthropus* skull that the straightening of the tympano-petrous axis is the result of a reduction process that affects the base of the temporal bone, especially the part jammed between the root of the zygoma and the mastoid process.

As to the position of the anthropoids, particularly the gorilla, the extension of the tympanic plate in the transverse direction is of importance. The tympanic plate measured from its most lateral projection (anterior border of the meatus) to the most medial point (exit of the Eustachian canal) is 28 to 33 mm. long in Solo man (average 30.1 mm.); in *Sinanthropus*, 32.7 mm.; in *Pithecanthropus robustus* (processus infratubarius included), 41.8 mm.; in modern man, 21 to 28.5 mm. (average 25.9 mm.). In the adult male gorilla the same distance is 62 mm., in the adult female gorilla, 45 mm., in chimpanzee it is 40 mm. The distance of the exposed petrous portion from apex to the pos-

terior border of the foramen jugulare is 34.7 mm. in Solo man, 27.5 mm. in modern man, 47 mm. in male gorilla, 37 mm. in female gorilla, 30 mm. in chimpanzee. In Solo man and modern man, the tympanic plate is shorter than the exposed petrous portion; in the anthropoids it is longer; in the gorilla it is longer than in the chimpanzee; and also in the gorilla it is much longer in the male than in the female. This indicates that the transverse expansion of the tympanic plate in anthropoids is not related to any auditory function. The expansion is caused by the same factor that produced the lateral prolongation of the articular tubercle and its shifting to the zygomatic process. It is correlated with the enormous development of the masticatory apparatus and, as such, is a secondary adaptation.

The entrance to the carotid canal is below the medial margin of the tympanic plate. The opening faces medially and backward. The canal first takes an upward direction and then turns forward and medially. In *Pithecanthropus robustus* the entrance lies in a vertical plane and faces almost directly backward. In *Sinanthropus* the conditions are similar to those in Solo man. In modern man the entrance is not covered by the tympanic plate, but the plate takes part in the formation of its lateral anterior wall. In the anthropoids the entrance is nearly free; the tympanic plate only occasionally encroaches on it from the lateral side. I am unable to see any difference in the character of the canal in Solo man and modern man; however, it is certainly much wider in the former than in anthropoids.

The foramen jugulare which opens just behind the carotid foramen is very pronounced on both sides of the two Solo Skulls VI and XI, in which the foramen is completely preserved. In both the right foramen is slightly wider than the left one. In all cases, a crest (processus interjugularis) also divides the anterior into a wide, rounded, lateral niche (fossa jugularis) which obviously lodges the bulbus jugularis and the foramen proper at the medial side. Compared with modern man, the foramen differs, as far as I am able to see, only in having a slightly greater transverse diameter; but it is certainly not smaller. The Solo foramen is much wider than in the anthropoids, where the foramen is

narrowed in sagittal direction and the lateral niche is considerably reduced.

MASTOID PORTION

The mastoid portion in Skull XI, left side, agrees almost completely in size and form with that of the *Sinanthropus* Skull V,¹ the largest skull of the *Sinanthropus* series. In Solo man as in *Sinanthropus*, we have a distinct incisura parietalis, a well-serrated sutura parieto-mastoidea, and a relatively large squamosal portion behind the mastoid process. The surface of this area differs somewhat in these two types. There is no sulcus supramastoideus between the cristae supramastoidea and mastoidea in Solo as in *Sinanthropus*, but, on the contrary, the markedly developed crista mastoidea passes upward to meet the supramastoid crest. The supramastoid crest consists of two blunt ridges, an anterior and posterior one, separated by what seem to be relics of a sutura squamosa-mastoidea. The base of the mammillary process of the mastoid is very large. In Solo Skull XI, left side, at the plane where the mammillary process is broken off, it measures 18 mm. in sagittal direction and 15 mm. in transverse direction. Its horizontal plane is triangular, with rounded angles and sides, a lateral, an anterior medial, and a posterior medial surface. A deep cleft at the medial side represents the incisura mastoidea. A characteristic feature of the process is its marked inward bend, a feature also typical of *Sinanthropus*. The tip of the mammillary process is preserved on either side of Skull VI; its height above the bottom of the incisura mastoidea is 9 mm. But in Skulls XI, V, and I the process was definitely higher, proving that its height is not inferior to that of modern man. In *Pithecanthropus robustus* (right side, in which the process itself is perfectly preserved) the height is 13 mm. This means that the old idea based on Neanderthal skulls should be revised. The temporal bones of Spy and Krapina man have a relatively weak and small mammillary process. In *Sinanthropus*, only Skulls III and XI have even a small process. Skull III, however, does not represent a completely mature individual; Skull XI is probably that of a female. In the other skulls the process

¹ Weidenreich, 1943, Pl. 9, Figs. 22-25.

is broken off, but the size of its preserved base, particularly in Skull V, suggests the process was strong and fairly prominent. In Solo man the mammillary process, regardless of sex, is as large and heavy as in any modern human skull. It is interesting to observe that *Pithecanthropus robustus* also has such a salient mastoid process; it is true that it is much smaller in mass than that of Solo man but not in height. However, Skull II of *Pithecanthropus erectus* has a very small, slightly developed process such as might occur in a female, but, even for a female, it is small. Therefore, the degree of development of the mastoid process cannot serve as a criterion of primitiveness, but the process is in any case typical of hominids. To claim that anthropoids have no mastoid process is not correct. In large male gorillas the process is usually more protuberant than in many examples of modern man, in *Pithecanthropus erectus*, or in *Sinanthropus* Skulls III and XI. However, its form and, in particular, the mastoid and occipital region medial to it differ in anthropoids and hominids.

In *Sinanthropus* the incisura mastoidea is a broad, shallow furrow extending far backward and upward, parallel to the sutura occipito-mastoidea and widening, fan-like, towards its end. Its breadth and shallowness vary in every case. The furrow is narrow in Skull V and very wide in Skull XII (left side). There is apparently some correlation between the depth and width of the furrow and the size of the mastoid process. In all the Solo skulls, however, the mastoid incisure is a short, deep, very narrow cleft at the medial side of the mastoid process, as though a part of the process were sharply cut off. The cleft does not extend beyond the process itself, nor does it widen. This kind of mastoid incisure as exhibited in Solo man is very common in modern man, although the form found in *Sinanthropus* can also be discovered not only in primitive races but also in European skulls. Unfortunately, in *Sinanthropus*, very little of the region between the mastoid and the occipital foramen is preserved. But in the areas available for comparison, there is a characteristic difference between *Sinanthropus* and Solo man. The mastoid incisure in *Sinanthropus* is bordered on its medial side by a very pronounced long ridge which is divided by the occipito-mastoid suture into a mastoid and an occipital ridge. In Solo man the mastoid portion

of this ridge has shifted so close to the mastoid process that it appears as a proper ridge, which has been called crista paramastoidea, while the occipital portion appears as an independent ridge which seems to be double-edged (crista occipito-mastoidea). Medial to this crest is a wide and relatively deep impression which, farther along medially, is bordered by the tuberositas postcondyloidea. This marked irregularity, with great differences in level, is characteristic of Solo man, but not of *Sinanthropus* or *Pithecanthropus robustus*. In the latter there is also some irregularity, but except for a very large and high paramastoid process close to the mastoid itself, behind and not medial to it, the elevations and depressions are more level. This difference may be due to a greater development of the nuchal musculature in Solo man.

The cerebral side of the temporal bone, together with that of the sphenoid, will be described below.

SPHENOID BONE

The sphenoid bone is very well preserved in Solo Skull VI, but it is not in as good condition in Skull XI. However, these are the only skulls of early hominids in which the sphenoid bone, especially the corpus and the pterygoid process, are sufficiently intact to permit comparison with modern man and anthropoids. Only parts of the greater wing are preserved in *Sinanthropus*.

Although the sphenoid, as a whole, clearly exhibits the human pattern and differs considerably from that of the anthropoids, some characteristic features reveal definite simian trends, while others are difficult to classify. Observed from the base, the root of the pterygoid process is very broad. The breadth is 16 mm. where the pterygoid rises from the corpus. It is only 12 mm. in the Tasmanian skull (A.M.N.H., V. L. 275), but it may be as low as 8 mm. in European skulls. The greatest width of the choanae, of which only the upper half is preserved, is 35 mm. In the Rhodesian skull, the corresponding distance is 28.5 mm.; in the Tasmanian skull it is 26 mm. Even the largest gorilla does not approach these dimensions in Solo man. The laminae of the pterygoid are broken off from the pterygoid at their origins; the line of attachment is very thick, indicating

that the laminae must have been much more robust than in modern man. It is difficult to determine whether there were air sinuses at the root area of the process. The X-ray photographs are not clear. In Skull IX, in which the base of the pterygoid is exposed, three separated niches on the left side may represent pneumatic cells. In *Pithecanthropus robustus* a large air sinus (28 mm., greatest length, to 13 mm., greatest breadth) is exposed on the left side.

The sphenoid region between the pterygoid process and the articular tubercle, more correctly named the spina angularis, is occupied by the foramen ovale and the foramen spinosum. The distance between the medial borders of the right and left foramina ovale is 52 mm. in Skull VI and 59 mm. in Skull XI. Distances of the same order can be found in modern human skulls and in large gorillas. In the Rhodesian skull, the distance is about 50 mm. However, the foramen ovale in Solo man differs from that of modern man in size, form, and position. These differences cannot be regarded as individual variations because Skulls VI and XI (the only specimens in which the foramen is preserved) have the same peculiarities on both sides. In all four cases the foramen is oval, as its name implies, but its longer diameter is oriented in sagittal and only slightly in medial direction. This also occurs in modern man, but very often its longer axis lies in a more transverse direction. Compared with that of modern man, the foramen in Solo man is much larger and, above all, the shorter diameter is much greater. These measurements are given in Table 13. But in contrast to conditions in modern man, in Solo man the foramen is not a simple perforation of the skull base but is in the form of an outlet at the bottom of the ovale pit which is 3 to 6 mm. deep. Furthermore, this pit has an accessory opening at the medial side near its anterior end. A second much smaller foramen perforates the base of this latter opening in medial direction; the canal is almost 5 mm. long. This accessory foramen (foramen ovale accessorium) occurs in three of the four skulls. It is not present on the right side of Skull VI in which, however, the main foramen is much larger than in the others (see above). This accessory foramen is a novelty. So far as I was able to learn, it has never previously been observed in any other

fossil hominid, in modern man, or in anthropoids. In *Pithecanthropus robustus* only the lateral borders are preserved; the rest is broken off. In this region only the foramen of Vesalius has previously been described as piercing the root of the great wing to the inner side of the foramen ovale which opens below into the scaphoid fossa at the base of the internal pterygoid plate and transmits a small vein. This description agrees with a small, slit-like, or

TABLE 13
MEASUREMENTS (IN MILLIMETERS) OF THE FORAMEN
OVALE IN SOLO MAN AND MODERN MAN

	Length	Breadth
Solo Skull VI		
Right	12.0	8.2
Left	9.3	6.2
Solo Skull XI		
Right	11.0	10.2
Left	6.3	7.2
Tasmanian skull (A.M.N.H., V. L. 275)		
Right	7.0	7.5
Left	5.0	4.5
European man		
Right	8.0	8.5
Left	4.0	3.5

oval opening medial to the foramen ovale at the very root of the pterygoid process, between the spurs of the lateral and medial laminae. It is not a rare occurrence in all races of modern man and varies greatly in size and form. It cannot be identical to the accessory foramen of Solo man, because the foramen and its canal process are both present in Solo man in all four skulls. In Skull XI, right side, the canal is opened by the fracture of the pterygoid. The entrance to this canal lies much higher up, at the surface of the pterygoid and more towards the medial side and not within the borderline of the foramen ovale. Additional canals in this region apparently admit blood vessels, but the one described is in exactly the same position in both skulls. Therefore, the foramen of Vesalius already exists in Solo man and has the appearance of a blood vessel entering the bone. How-

ever, the foramen ovale accessorium is different in character. It is a smaller partition of the main foramen and lies medial to it. On the cerebral side, the topographic relations are the same. For all these reasons, I regard the accessory foramen as the outlet for the smaller or motor root of the mandibular nerve of the trigeminal nerve. This smaller root lies beneath the Glaserian ganglion and, in modern man, passes on the medial side of the main nerve through the foramen ovale to unite with it after its exit from the skull. In Solo man the two roots continue, obviously separated, and only unite outside, but still within the pit of the foramen ovale itself, as described above.

None of the anthropoids or other apes have any indication of an accessory foramen ovale. It is interesting, however, that especially in the gorilla the foramen ovale is more like a canal than a simple hole; it can extend to 20 mm. in length. It never runs directly downward, but always slightly forward, corresponding to the forward direction of the face. In Solo man the wide pit, on the bottom of which the foramen is situated, is apparently equivalent to the "canal" in the gorilla, and its formation is due to thickness of the cranial bones. In gorilla there is an abundant pneumatization, particularly in this sphenoid region. In Solo man the bone appears to be solid.

Behind the foramen ovale and slightly lateral to it is the foramen spinosum, an independent, relatively wide foramen present on both sides of Solo Skulls VI and XI. It lies close to the Eustachian fossa and well anterior to the spina angularis. In comparison with that of modern man there is virtually no difference, except that the rim separating the foramen from the adjacent sunken pyramid is much broader in Solo man. In modern man this rim participates in the reduction of the entire region as described above.

Another feature deserves mention. The breadth of the base of the ala magna measured from the notch of the fissura orbitalis inferior above the exit of the foramen rotundus to the anterior end of the foramen ovale, is 17.5 mm. in Solo Skull VI (right) and 22 mm. in Skull XI (left). The corresponding breadth in modern man reaches 15 mm. only in large, heavy skulls.

One more noteworthy structure is the strongly developed crista orbitalis which is preserved on the right side of Skull VI. This crista

is the thickened edge at the point of contact of the facies temporalis and the facies of the greater wing. The crista orbitalis continues into the crista infratemporalis. All these features can also be found in modern man, but because of the generally greater robustness of the Solo skulls they are much more prominent and strike the eye more than in the former. For the same reason, the passage from the facies temporalis to the lateral surface of the lamina lateralis of the pterygoid process is more abrupt and more marked in Solo man.

The formation of the pterion region has been discussed above; it is unnecessary to review it here.

ETHMOIDAL BONE

The sole remains of the ethmoidal bone consist of its upper part which fills the incisura ethmoidalis of the frontal bone. It is available only as it appears on the fracture of this region in Solo Skull VI. It resembles a horizontal section from the nasion and interorbital region backward to the entrance into the sphenoid sinuses and the fissura orbitalis inferior. This cut through the ethmoidal bone is a long quadrangle, with its two sides from the lacrimal bones back to the sphenoid almost parallel. The transverse diameter at the lacrimae, which corresponds to the posterior interorbital breadth, measures 32 mm., while the transverse diameter of the quadrangle at the corpus of the sphenoid is 28 mm. This means that the two sides converge slightly backward.

The septum nasi ossium and the roof of the nasal cavity on either side of the septum are observable for their entire length. Lateral to this is the labyrinth. Four cellulae ethmoidales are recognizable on either side. The most anterior of these cells is larger than the others and communicates widely with the frontal sinus. In the rear the sphenoid rostrum, in connection with the vomer, appears as the direct continuation of the septum ossium. The apertura of the sinus sphenoidalis lies on either side of the rostrum.

Only the uppermost part of the lamina papyracea is intact. In the interna fronto-ethmoidalis the foramen ethmoidale posterium is very distinct and relatively wide.

THE CEREBRAL SURFACE OF THE BASE OF THE SKULL

The cerebral surface of the base of the skull is completely preserved in Solo Skull VI, and in

Skull XI except for the anterior fossa cerebri. The base, however, is not easily accessible for study because in both skulls the braincase is closed and the hole in Skull XI is not wide enough to permit inspection. As we did not dare risk opening the braincase, our only choice was to remove the matrix adhering to the interior through the foramen occipitale and through the artificial hole in the roof of the orbits in Skull XI and to make rubber endocasts through the opening. The positive casts made from the endocasts show the cerebral surface of the base. Unfortunately, it was impossible to clean the entire surface. In some regions, especially the anterior fossa cerebri in Skull VI and the media fossa in Skull XI, the matrix, which consisted of hard crystals adhering to the bone, could not be completely removed. Consequently, the results are not satisfactory. But control was possible, as the casts also showed the outer surface of the base with all the essential outlets.

The cerebral surface of the bases of Skulls VI and XI are almost the same size. For example, in sagittal direction the distance from the left foramen rotundum to the eminentia cruciata of the occipital bone is 106 mm. in both skulls; in transverse direction the distance between the medial sides of the two oval foramina is 57 mm., and that between the anterior ends of the two jugular foramina is 52 mm.

The most characteristic feature of the skulls is the flatness of the base as compared with that of modern man. Each of the three fossae cerebri, the anterior, medial, and posterior, is at a higher level, exactly as it is in modern man, but the difference in height between the three levels is much less than in modern man. The reason is that the posterior fossa itself is not only much flatter than in modern man, but also descends much less. This difference can best be noted on mid-sagittal sections through the whole skull of Solo man and modern man as illustrated in Fig. 21. In order to make this comparison more illuminating, the negative instead of the positive prints of the empty braincase are reproduced, giving the illusion that the shells are not empty, but contain the brains wrapped in their membranes. This method was used by E. Landau¹ to show the topographical relation between braincase and brain. Both skulls (Solo Skull XI and that of a modern European, Pl.

45) are oriented in the Frankfort Horizontal. Even a glance at the illustrations shows the difference. The modern human brain with the braincase (Pl. 45c) is bent downward behind a transverse axis passing through the two mandibular joints at the outside of the skull and to the sella turcica on the cerebral side. As a result, the occipital half of the skull behind the transverse axis makes a sharper angulation with the frontal half. In the Solo skull (Pl. 45b) there is no such curvature; the braincase and brain are relatively flat. Therefore differences in the levels of the floors of the three cerebral fossae are small compared with those of modern man.

In modern man the curvature of the braincase in the sagittal direction is obviously due to the deflection of its base. The floor of the anterior cerebral fossa, the uppermost of the three fossae, is represented on the mid-sagittal section by a line passing from the foramen caecum to the tuberculum sellae. This line is almost horizontal. Beyond the tuberculum sellae the line turns downward towards the dorsum sellae, whence it runs along the clivus to the foramen occipitale. This is the steepest decline. It forms an obtuse angle with the horizontal floor of the anterior fossa. This angle is about 115° in the European skull depicted in Pl. 45c. In Solo man (Pl. 45b) there is also a decrease, but this decline of the clivus, compared with the horizontal floor of the anterior fossa, is much less pronounced, the angle measuring about 140°.

There are additional interesting differences. The distance from the foramen caecum to the dorsum sellae is 74 mm. in Solo man, 67 mm. in the European (Pl. 45c) and in the Tasmanian skull (A.M.N.H., V. L. 275) it is 59 mm. The length of the clivus from the dorsum sellae to the basion is 28 mm. in Solo Skull VI and 18 mm. in Skull XI; it is 38 mm. in the European and 45 mm. in the Tasmanian. The direct distance from the foramen caecum to the basion is 97 mm. in Solo Skull VI and 95 mm. in Skull XI compared with 86 mm. in the European and 91 mm. in the Tasmanian. The nasion-basion lines measured at the outside of the four skulls in question are 111 mm. in Solo Skull VI, 112 mm. in Skull XI, 101 mm. in the European, and 103 mm. in the Tasmanian skull. These figures show that the over-all length of the interior and exterior of the skull base is shorter in modern man than in Solo man, as I have al-

¹ Landau, 1909, 645-646; 1923, 5-6, Figs. 1, 2.

ready¹ shown to be true of modern man when compared with *Sinanthropus*. This shortening is caused by the deflection of the base. Furthermore, the figures show that the floor of the anterior fossa of modern man is shorter, while the clivus is longer. In Solo Skull XI, the clivus is only 18 mm. long, in Skull VI it is 28 mm. long which, in any case, is much shorter than is usual in modern man, where the average is around 40 mm.

However, this length depends largely on the height of the dorsum sellae which is extremely variable in modern man. The height of the klition (the mid-sagittal point of the dorsum) above the deepest point of the sella turcica varies from 1 or 2 mm. to 12 mm. in adult man. This variation in height of the dorsum sellae is of interest because of its bearing on the problem of evolution. In a recent paper² I drew attention to the great variability of the dorsum in anthropoids, and in the size and form of the sella turcica. Very little is known about these conditions in man and anthropoids. Cave³ showed that the interclinoid portion is very independent of the rest of the bone and that the stereotype of the dorsum occurs in only 30 per cent of cases. In the two Solo specimens the processus clinoidei posteriores are well developed, but the interclinoid portion of the dorsum in Skull XI is no more than a "limen" which demarcates the clivus from the depression representing the fossa hypophyseos. This depression is not very deep, certainly much shallower than is usual in modern man. Measured at the limen, the clivus in Solo Skull X is only 9 mm. thick, but in Skull VI it is 11 mm. The difference is due to a higher interclinoid portion in Skull VI. At the deepest point of the fossa the bone is only 2 mm. thick in Skulls XI and VI. In the European and Tasmanian skulls used for comparison, the thickness of the bone at the floor of the fossa is 16 mm. in the former and 18.5 mm. in the latter. To learn whether the thickness of the bone has any bearing on the size and extent of the sinus sphenoidalis beneath the fossa, I studied their relation on 21 mid-sagittal sections through European skulls illustrated in natural size and with all necessary

details by Ranke.⁴ The average thickness of the basilar bone beneath the fossa is 18 mm. in males and 14.6 mm. in females. In 62.5 per cent of males and 53.9 per cent of females the sinus sphenoidalis extends so far back that it attains a perpendicular position at the deepest point of the fossa. From these figures it follows that sex does influence the thickness of the corpus of the sphenoid beneath the fossa. This greater thickness of the male is in full accord with the generally more massive development of male skeletons. Sex apparently plays the same role in the penetration of the sinus. In males, that is, in thicker bones, the sinus extends farther back than in thinner bones. In Solo Skull XI the sinus sphenoidalis on either side has been exposed by the large hole in the region of the fossa anterior cerebri. Where it is exposed, that is, exactly at a transverse plane through the two oval foramina, the sinus occupies the entire corpus sphenoidalis. It has a very thin roof but somewhat thicker base. The height of the sinus at the point where the breakage occurs is 15 mm., that of the whole corpus is 18.5 mm. In modern man the height at the corresponding place is 27 mm. in males and 23.7 mm. in females. The posterior end of the sinus, which is well preserved on both sides, is about 5 mm. It extends back only to the level of the tuberculum sellae. The fossa is complete beyond the compass of the sinus. In Solo Skull VI it is not so well preserved as in Skull XI. While the slope from the tuberculum sellae region down to the fossa hypophyseos is clearly recognizable in Skull VI, this area is broken and partly covered with matrix in Skull XI. The entrances to the sinus sphenoidalis are clear, but the areas behind are broken. Nevertheless, the position of the tuberculum sellae is marked, as is also the region of the fossa hypophyseos up to the dorsum sellae. The mid-sagittal distance from the tuberculum sellae to the klition (dorsum sellae), that is, the length of the fossa hypophyseos, is 22 mm. in Skull XI and in Skull VI. The depth of the infundibulum is 9 mm. The breadth, the distance between the medial border of the sulci carotici is 22 mm.

According to Pruett's⁵ tabulations of measurements for different races, males and females,

¹ Weidenreich, 1947, 400 *et seq.*

² Weidenreich, 1947, 404-406, 409-440.

³ Cave, 1933.

⁴ Ranke, 1892.

⁵ Pruett, 1928, Table E.

the length and breadth of the fossa of Solo man are double the average length and breadth of that of modern man, while the depth is about the same. Even the maximum values observed in length and breadth in modern man are considerably lower than the values observed in Solo man. The mean measurement of length plus breadth plus depth is 17.7 in Solo man against 9.8 in modern man. Pruett calculated the "module" of the fossa, according to Hrdlička's method by multiplying the mean measurement of the fossa (17.7 in Solo Skull XI) by 1000 and dividing the product by the circumference of the skull. The circumference of Solo Skull XI is 537 mm. The module of the fossa is, therefore, 33. In modern man this module varies from 16.83 to 28.85, with an average of 21 in males and females, whites and blacks, according to Pruett.¹ From these figures it follows that the module of the fossa hypophyseos of Solo man represents an increase of 57 per cent over that of modern man.

If all these figures give a reliable idea of the size of the pituitary gland, the result would suggest that Solo man, taking into consideration the extraordinary thickness of the cranial bones and the large size of the skull, had a large gland. This result would be welcomed by all who believe in such a relationship. But I am skeptical, because the dimensions of the sella turcica are not identical with the dimensions of the gland. The gland is surrounded by the sinus circularis (cavernosus), and it is not the size of the gland alone but also the size of the sinus that determines the volume of the sella. On the other hand, the difference between the volume of the sella of Solo man and modern man is so great that the larger size of the sella of Solo man may be attributed to the size of the pituitary gland, particularly since the sulci which lodge the other sinuses in Solo man are smaller rather than larger than in modern man.

The sella turcica of Solo man exhibits other characteristic features. Compared with modern man it lies farther back. A transverse plane through the two foramina rotunda crosses the tuberculum sellae, as it does in modern man, but the slope from the tubercle downward to the bottom of the fossa is much longer than in modern man; consequently, the center of the

fossa falls behind a transverse plane through the two oval foramina. It lies at the same transverse plane as the lingula sphenoidalis and the notch of the sulcus caroticus.

A transverse (coronal) section through the sphenoidal corpus at the center of the fossa hypophyseos has the form of a broad-based triangle with its apex cut off. This plane, slightly depressed, represents the bottom of the fossa. In other words, in modern man and in anthropoids, the sphenoidal corpus itself has no depression, but the area called "fossa" is a circular or quadrangular field on top of the cerebral surface of the corpus, bounded by a high frame consisting either of bars on each side or only of

TABLE 14
MEASUREMENTS (IN MILLIMETERS) OF THE FOSSA
HYPOPHYSEOS IN A SOLO SKULL
AND IN MODERN MAN

	Solo Skull XI	Modern Man (Pruett)
Length	22	10.7 (6-16)
Breadth	22	10.0 (7-17.5)
Depth	9	8.7 (3-15)

tubercles or processes on the four corners. Solo man has a real fossa. Nothing is known about these conditions in other hominids. Pycraft mentions the region in his description of the interior of the cranium of Rhodesian man, but he does not refer to the fossa hypophyseos.

I cannot discuss the fossa anterior cerebri in detail. It is preserved only in Skull VI, but is covered with matrix that could not be removed. The fossa appears to be more convex over the orbits and, therefore, deeper in the ethmoidal region than is usual in modern man. Furthermore, there is no indication of the presence of a crista galli (see above). Apparently the ledge formed by the lesser wing of the ala parva of the sphenoid, the processus clinoides anteriores, and the tuberculum sella overhang and project less than in modern man, and the wing does not rise laterally towards the wall but spreads in a more horizontal plane. Pycraft observed the same conditions in the Rhodesian skull.

With regard to the middle fossa of the Rhodesian skull, Pycraft says:

¹ Pruett, 1928, Table E.

The most conspicuous feature of the middle fossa is its shallowness, owing to the fact that the orbito-sphenoidal wing . . . spreads outward in a horizontal plane, thereby decreasing the depth of the fossa.¹

This is exactly the situation in Solo man. But it is not the only reason for the shallowness of the fossa; the pyramid that forms its posterior wall rises to a much lower level in Solo man than in modern man and its superior surface does not sink down to the bottom of the fossa as abruptly as in modern man but has a more gradual and

¹ Pycraft, 1928, 11.

gentle incline. I have described the same conditions in *Sinanthropus*.² The whole pyramid is flat, prostrate; its anterior and posterior surface meet at a right angle (Skull VI). In modern man the pyramid rises to a much higher level, the two surfaces meet at an obtuse angle, and the crest forms a fairly sharp edge. The flatness in Solo man and the height in modern man are shown when the sagittal length of the pyramid is measured. The distance from the foramen fissure at the anterior . . .

² Weidenreich, 1943.

LITERATURE CITED

- BLACK, DAVIDSON
1931. On an adolescent skull of *Sinanthropus Pekinensis* in comparison with an adult skull of the same species and with other hominid skulls, recent and fossil. *Palaeont. Sinica*, ser. D, vol. 7, fasc. 2, pp. 1-144.
- BOULE, MARCELLIN
1937. Le sinanthrope. *L'Anthropologie*, vol. 47, pp. 1-22.
- BROOM, R., AND C. W. H. SCHEPERS
1946. The South African fossil ape-men. The Australopithecinae. *Mem. Transvaal Mus.*, no. 2.
- CAVE, A. J. E.
1933. Dorsum sellae. *Jour. Anat.*, vol. 68, pp. 137-139.
- DREYER, T. F., AND A. LYLE
1931. New fossil mammals and man from South Africa. *Bloemfontein*, pp. 1-60.
- DUBOIS, EUGÈNE
1922. The proto-Australian fossil man of Wadjak, Java. *Proc. Sect. Sci., K. Akad. Wetensch. Amsterdam*, vol. 23, pp. 1013-1051.
1932. Early man in Java. *Nature*, vol. 130, no. 3270, p. 20.
1936. Racial identity of *Homo soloensis* Openoorth (including *Homo modjokertensis* von Koenigswald) and *Sinanthropus pekinensis* Davidson Black. *Proc. Sect. Sci., K. Akad. Wetensch. Amsterdam*, vol. 39, pp. 1180-1185.
1937. On the fossil human skulls recently discovered in Java and *Pithecanthropus erectus*. *Man*, vol. 37, pp. 1-7.
1940. The fossil human remains discovered in Java by Dr. G. H. R. von Koenigswald and attributed by him to *Pithecanthropus erectus*, in reality remains of *Homo wadjakensis* (syn. *Homo soloensis*). *Proc. Sect. Sci., K. Akad. Wetensch. Amsterdam*, vol. 43, pp. 494-496, 842-851, 1268-1275.
- ELBERT, J.
1908. Ueber das Alter der Kendeng-Schichten mit *Pithecanthropus erectus* Dubois. *Neues Jahrb. f. Min., Geol., u. Paläont., suppl.* vol. 25, pp. 648-662.
- KLAAUW, C. J. VAN DER
1931. The auditory bulla in some fossil mammals, with a general introduction to this region of the skull. *Bull. Amer. Mus. Nat. Hist.*, vol. 62, pp. 1-352.
- KOENIGSWALD, G. H. R. VON
1933a. Beitrag zur Kenntnis der fossilen Wirbeltiere Javas. I. Teil. *Wetensch. Meded. Dienst van den Mijnbouw in Nederlandsch Indië*, no. 23, pp. 1-127.
1933b. Ein neuer Urmensch aus dem Diluvium Javas. *Centralbl. f. Min., Geol., u. Paläont., Abt. B*, pp. 29-42.
1937. A review of the stratigraphy of Java and its relation to early man. In MacCurdy, George Grant (ed.), *Early man*. Philadelphia and New York, pp. 23-32.
- KOENIGSWALD, G. H. R. VON, AND FRANZ WEIDENREICH
1939. The relationship between *Pithecanthropus* and *Sinanthropus*. *Nature*, vol. 144, pp. 926-929.
- LANDAU, E.
1909. Das Gehirnrelief der Fossa cranii anterior. *Gegenbaurs Morph. Jahrb.*, vol. 39, pp. 645-646.
1923. Anatomie des Grosshirns. Formanalytische Untersuchungen. Bern.
- LEAKEY, L. S. B.
1946. Fossil finds in Kenya: ape or man? *Yearbook, Phys. Anthropol.*, pp. 29-33.
- MARTIN, HENRI
1923. Recherches sur l'évolution du Moustérien dans le gisement de la Quina (Charente). *Bull. et Mém. Soc. Archéol. et Hist., Charente*, ser. 8, vol. 14, pp. 1-140.
- MARTIN, RUDOLF
1928. Lehrbuch der Anthropologie in systematischer Darstellung. Mit besonderer Berücksichtigung der Anthropologischen Methoden für Studierende, Ärzte und Forschungreisende. Jena.
- OPPENOORTH, W. F. F.
1932a. *Homo (Javanthropus) Soloensis*. Een Plistoceene mensch van Java. *Wetensch. Meded. van den Dienst van den Mijnbouw Nederlandsch-Indië*, no. 20, pp. 49-63.
1932b. De vondst van paleolithische menselijke schedels op Java. *De Mijningenieur, Bandoeng*, no. 5, pp. 106-115.
1932c. Ein neuer diluvialer Urmensch von Java. *Nat. u. Mus., Frankfurt*, vol. 62, no. 9, pp. 269-279.
1936. Een prehistorisch cultuur-centrum langs de Solo-Rivier. *Tijdschr. K. Nederlandsch Aardrijkskundig Genootsch.*, vol. 53, pp. 399-411.
1937. The place of *Homo soloensis* among fossil men. In MacCurdy, George Grant (ed.), *Early man*. Philadelphia and New York, 349-360.

PETERS, H. B.

1931. Über Naht-Anomalien und Variationen am Primatencranium. *Zeitschr. f. Morph. u. Anthropol.*, vol. 30, pp. 317-372.

PRUETT, BURCHARD S.

1928. On the dimensions of the hypophyseal fossa in man. *Amer. Jour. Phys. Anthropol.*, vol. 11, pp. 205-222.

PYCRAFT, W. P.

1928. Description of the human remains. In Pycraft, W. P., *et al.*, Rhodesian man and associated remains. London, pp. 1-51.

RANKE, JOHANNES

1892. Ueber einige gesetzmässige Beziehungen zwischen Schädelgrund, Gehirn und Gesichtsschädel. *Beitr. zur Anthropol. u. Urgesch. Bayerns*, vol. 10, pp. 1-132.

SCHULTZ, ADOLF

1915. Form, Grösse und Lage der squama temporalis des Menschen. *Zeitschr. f. Morph. u. Anthropol.*, vol. 19, pp. 352-380.

SERGI, SERGIO

1909. Sull asimmetria dei condili occipitali nell'uomo. *Atti. Soc. Romana Anthropol.*, vol. 15, pp. 173-186.
1944. Craniometria e cranio grafia del primo paleontropa di Saccopastore. *Ric. di Morf.*, Rome, vol. 20-21, pp. 1-59.

SOERGEL, W.

1914. Stegodonten aus den Kendengschichten auf Java. *Palaeontographica*, suppl. vol. 4, pp. 1-24.

STRECKER, CARL

1887. Ueber die Condylen des Hinterhauptes. *Arch. f. Anat. u. Physiol.*, Leipzig, Anat. Abt., pp. 301-338.

VAN STEIN CALLENFELS, P.

1936. L'industrie osseuse de Ngandong. *L'Anthropologie*, vol. 46, pp. 359-362.

VIRCHOW, R.

1872. Untersuchung des Neanderthal-Schadels. *Zeitschr. f. Ethnol.*, Berlin, vol. 4, pp. 157-165.

WEIDENREICH, FRANZ

1932. Über pithekoide Merkmale bei *Sinanthropus pekinensis* und seine stammesgeschichtliche Beurteilung. *Zeitschr. f. Anat. u. Entwickl.*, vol. 99, pp. 212-253.
1940. The torus occipitalis and related structures and their transformation in the course of human evolution. *Bull. Geol. Soc. China*, vol. 19, pp. 480-558.
1941. The brain and its role in the phylogenetic transformation of the human skull. *Trans. Amer. Phil. Soc.*, new ser., vol. 31, pp. 321-442.
1943. The skull of *Sinanthropus pekinensis*: a comparative study on a primitive hominid skull. *Palaeont. Sinica*, new ser. D, no. 10, whole ser. no. 127, pp. 1-484.
1945. Giant early man from Java and South China. *Anthrop. Papers Amer. Mus. Nat. Hist.*, vol. 40, pp. 1-134.
1946. Apes, giants, and man. Chicago.
1947. Some particulars of skull and brain of early hominids and their bearing on the problem of the relationship between man and anthropoids. *Amer. Jour. Phys. Anthropol.*, new ser., vol. 5, pp. 387-428.

WETMORE, A.

1940. Avian remains from the Pleistocene of central Java. *Jour. Palaeont.*, vol. 14, pp. 447-450.

EXPLANATION OF PLATES

16. Excavation of Ngandong Skull VI and scene along the Solo River, near Menden, north of Ngandong
 - a. Excavation of Ngandong Skull VI. The skull, with a heavy encrustation, is resting on its vault. To the right is the late C. ter Haar, the discoverer of the site
 - b. Scene along the Solo River, near Menden, north of Ngandong, during the dry season. The large sand bank in the middle might reflect the original conditions of the Ngandong site. To the left the 7-meter terrace, and to the right the 20-meter one, can be observed. Photographs by G. H. R. von Koenigswald
17. Excavation and cross-section through the Ngandong terrace
 - a. Excavation in the Ngandong terrace, June, 1932
 - b. Cross-section through the Ngandong terrace showing sand and gravels. The dark line indicates the original surface of the layers. Photographs by G. H. R. von Koenigswald
18. Solo Skull I. $\times \frac{1}{2}$
 - a. Vertical view
 - b. Basilar view
 - c. Frontal view
 - d. Occipital view
19. Solo Skulls I and II. $\times \frac{1}{2}$
 - a. Skull I, lateral view, right side
 - b. Skull I, lateral view, left side
 - c. Skull II, left side
 - d. Skull II, isolated frontal bone, viewed from in front
 - e. Skull II, isolated frontal bone, cerebral side
 - f. Skull II, isolated frontal bone, viewed from below
20. Solo Skulls III and IV. $\times \frac{1}{2}$
 - a. Skull III, lateral view, left side
 - b. Skull III, viewed from above
 - c. Skull III, viewed from behind
 - d, e. Fragment of a right sphenoid angle portion of a right parietal bone viewed from the outside and inside; possibly belongs to Skull III, but there is no clear contact
 - f. Skull IV, viewed from above
21. Solo Skull IV. $\times \frac{1}{2}$
 - a. Lateral view, left side
 - b. Lateral view, right side
 - c. Viewed from below
 - d. Viewed from in front
 - e. Large lesion at the top of the calotte, viewed from above, left side, and behind
22. Solo Skull V. $\times \frac{1}{2}$
 - a. Vertical view
 - b. Basilar view
 - c. Frontal view
 - d. Occipital view
23. Solo Skulls V and VI. $\times \frac{1}{2}$
 - a. Skull V, lateral view, left side
 - b. Skull V, lateral view, right side
 - c. Skull VI, vertical view
 - d. Skull VI, basilar view
24. Solo Skull VI. $\times \frac{1}{2}$
 - a. Frontal view
 - b. Occipital view
 - c. Lateral view, right side
 - d. Lateral view, left side
 - e. Left side, injury at top of left parietal bone
25. Solo Skulls VII and VIII. $\times \frac{1}{2}$
 - a. Skull VII, fragment of a right parietal bone, outer side
 - b. Skull VII, fragment of a right parietal bone, cerebral side
 - c. Skull VIII, right and left parietal bones, right side
 - d. Skull VIII, right and left parietal bones, left side
 - e. Skull VIII, right and left parietal bones, viewed from in front
 - f. Skull VIII, right and left parietal bones, viewed from behind
26. Solo Skull IX. $\times \frac{1}{2}$
 - a. Vertical view
 - b. Frontal view
 - c. Occipital view
 - d. Lateral view, right side
27. Solo Skulls IX and X. $\times \frac{1}{2}$
 - a. Skull IX, lateral view, left side
 - b. Skull X, vertical view
 - c. Skull X, basilar view
 - d. Skull X, lateral view, right side
28. Solo Skulls X and XI. $\times \frac{1}{2}$
 - a. Skull X, lateral view, left side
 - b. Skull X, frontal view
 - c. Skull X, occipital view
 - d. Skull XI, vertical view
29. Solo Skull XI. $\times \frac{1}{2}$
 - a. Basilar view
 - b. Frontal view
 - c. Occipital view
30. Solo Skull XI
 - a. Lateral view, left side. $\times \frac{1}{2}$
 - b. Lateral view, right side. $\times \frac{1}{2}$
 - c. Supraorbitals viewed from in front and below. $\times \frac{3}{4}$
 - d. Pterion region. $\times \frac{3}{4}$
 - e. Foramen occipitalis shown from the side, rotated backward and upward. $\times \frac{3}{4}$

31. Solo Tibiae A and B. $\times \frac{1}{2}$
 - a. Tibia A, anterior view
 - b. Tibia A, posterior view
 - c. Tibia A, medial view
 - d. Tibia A, lateral view
 - e. Tibia B, distal articular facet, viewed from below
 - f. Tibia B, viewed from above
 32. Solo Tibia B. $\times \frac{1}{2}$
 - a. Anterior view
 - b. Posterior view
 - c. Medial view
 - d. Lateral view
 33. Solo Skull XI, lateral view. $\times 1/1$
 34. Solo Skull XI, lateral view, key to landmarks
 35. Solo Skull XI
 - a. Frontal view. $\times 1/1$
 - b. Key to landmarks
 36. Solo Skull XI
 - a. Occipital view. $\times 1/1$
 - b. Key to landmarks
 37. Solo Skull XI
 - a. Vertical view. $\times \frac{1}{2}$
 - b. Key to landmarks
 38. Solo Skull VI
 - a. Basilar view. $\times \frac{1}{2}$
 - b. Key to landmarks
 39. Solo Skull XI, basilar view. $\times 1/1$
 40. Solo Skull XI, key to landmarks
 41. Reconstruction of skull of Solo Man. $\times \frac{3}{4}$
 42. Solo Skull VI, posterior section of the base, viewed from below; left side with key to landmarks. $\times 1/1$. Cf. Pl. 24d
 43. Solo Skull XI
 - a. Anterior view. $\times \frac{1}{2}$
 - b. Key to landmarks
 44. Solo Skull XI, Australian and Tasmanian skulls, Solo Skulls VI and V. $\times 1/1$
 - a. Solo Skull XI, area around the foramen ovale
 - b. Australian skull (99-8160), area around the foramen ovale
 - c. Tasmanian skull (A.M.N.H., V.L. 275), area around the foramen ovale
 - d. Solo Skull VI, fissura orbitalis superior and surrounding area
 - e. Solo Skull V, pyramid and adjacent area
- Abbreviations:* ast, apertura semicanilis tubae auditivae; av, alae vomeris; cc, canalis caroticus; ce, cellulae ethmoidales; cit, crista infratemporalis; co, condylus occipitalis; com, crista occipito-mastoidea; cp, crista paramastoidea; cv, canalis vidianus; fep, foramen ethmoidale posterius; fl, foramen lacerum; fm, fossa mandibularis; fo, foramen ovale; foa, foramen ovale accessorium; fop, foramen opticum; fos, fissura orbitalis superior; fp, fossa postjugularis; fr, foramen rotundum; fs, foramen spinosum; fsm, facies spheno-maxillaris; fsma, foramen stylo-mastoideum; fv, foramen vesalii; i(f)j, incisura (foramen) jugularis; im, incisura mastoidea; or, orbital roof; p, pyramid; pae, porus acusticus externus; pit, processus infratubaris; pj, processus jugularis; pm, processus mastoideus; pp, processus pterygoideus; ps, processus styloideus; pz, processus zygomaticus; sa, spina angularis; som, sutura occipitomastoidea; sp, spina petrosa; sps, sulcus processus styloideus; ssp, sinus sphenoidale; sta, sulcus tubae auditivae; t, tympanum; tpc, tuberositas postcondyloidea; v, vomer
45. Endocasts *in situ* of gorilla (A.M.N.H., C.A. No. 507), Solo Skull XI, and modern man (European). $\times 2/5$
 46. Key to landmarks on endocasts of gorilla, Solo Skull XI, and modern man (European) shown in Pl. 45
 47. X-ray photographs of Solo Skulls VI and XI. $\times \frac{1}{2}$
 - a. Solo Skull VI
 - b. Solo Skull XI
- X-rays by Dr. Ramsey Spillman

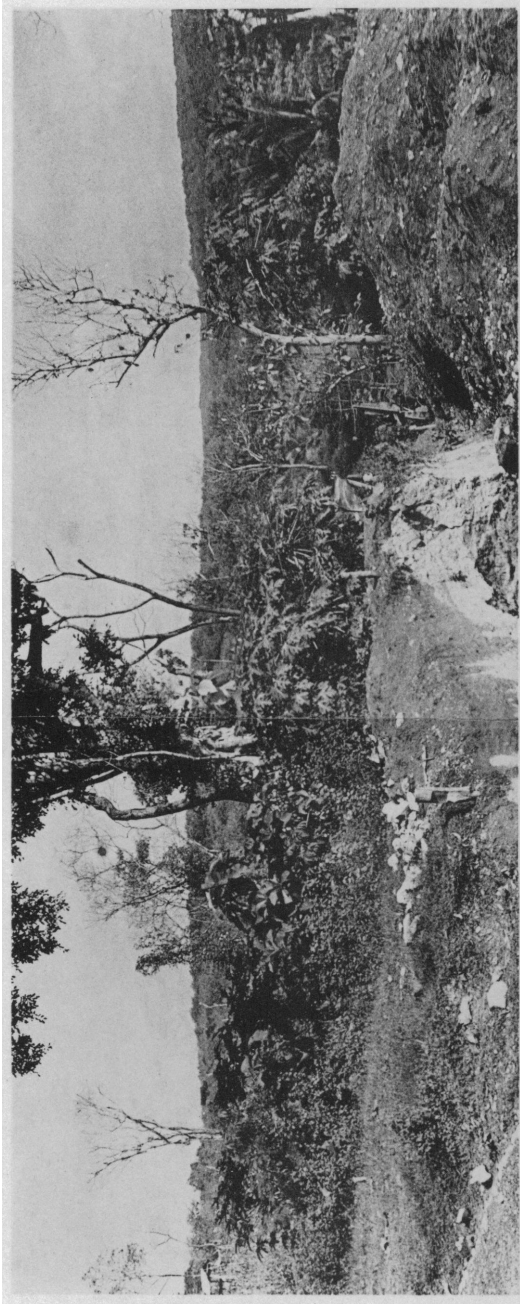


A



B

Excavation of Ngandong Skull VI and scene along the Solo River, near Menden, north of Ngandong

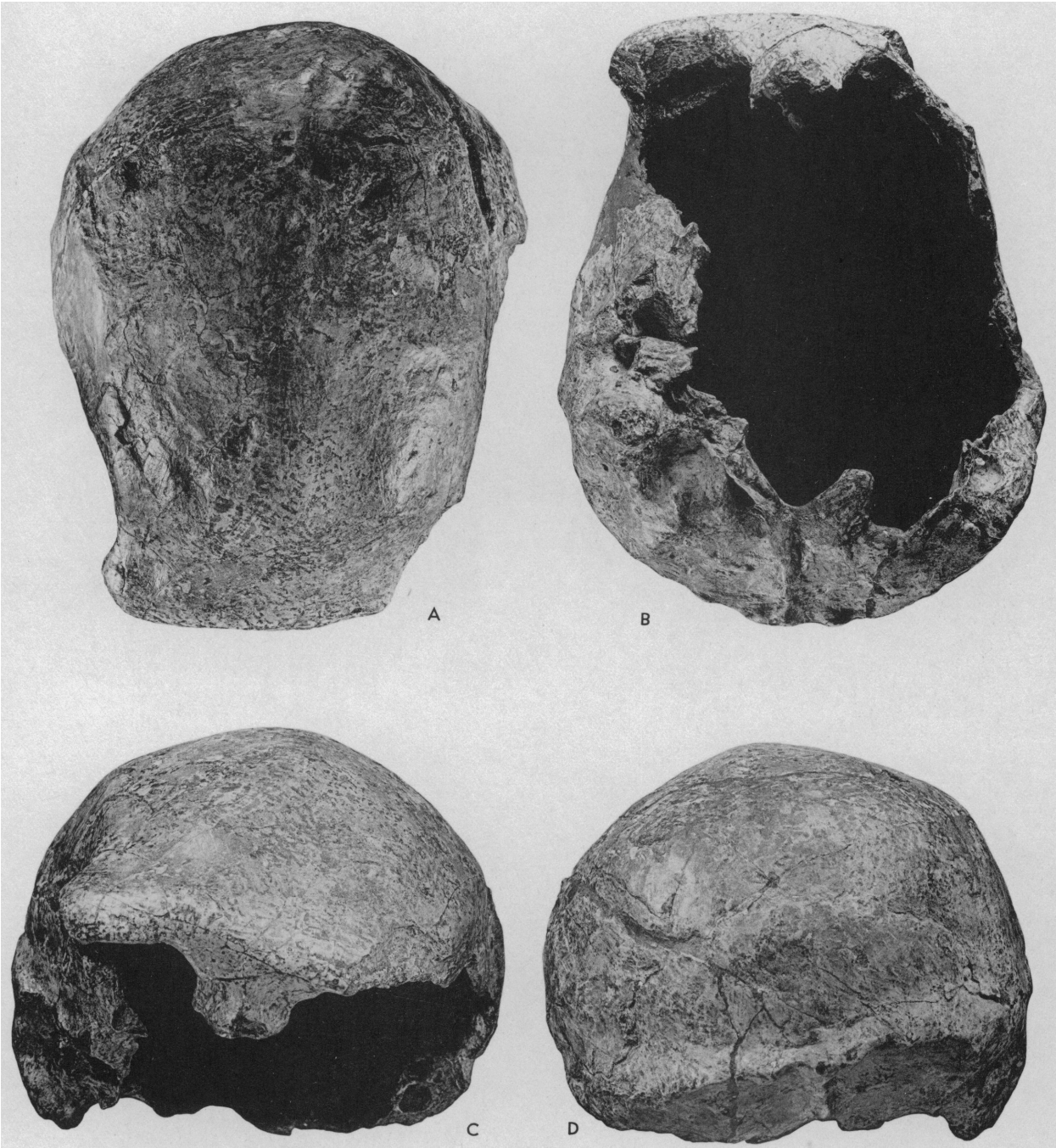


A



B

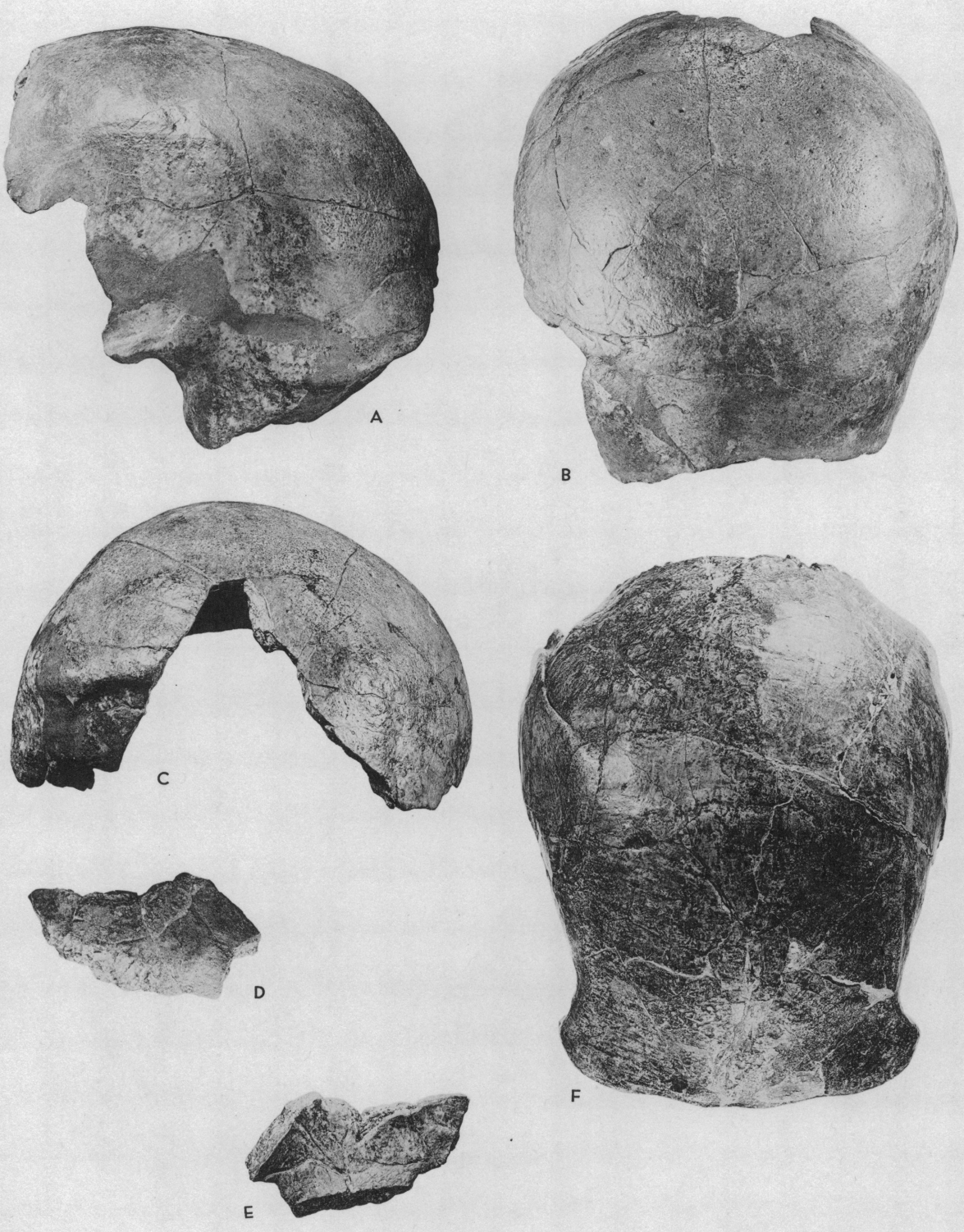
Excavation and cross-section through the Ngandong terrace



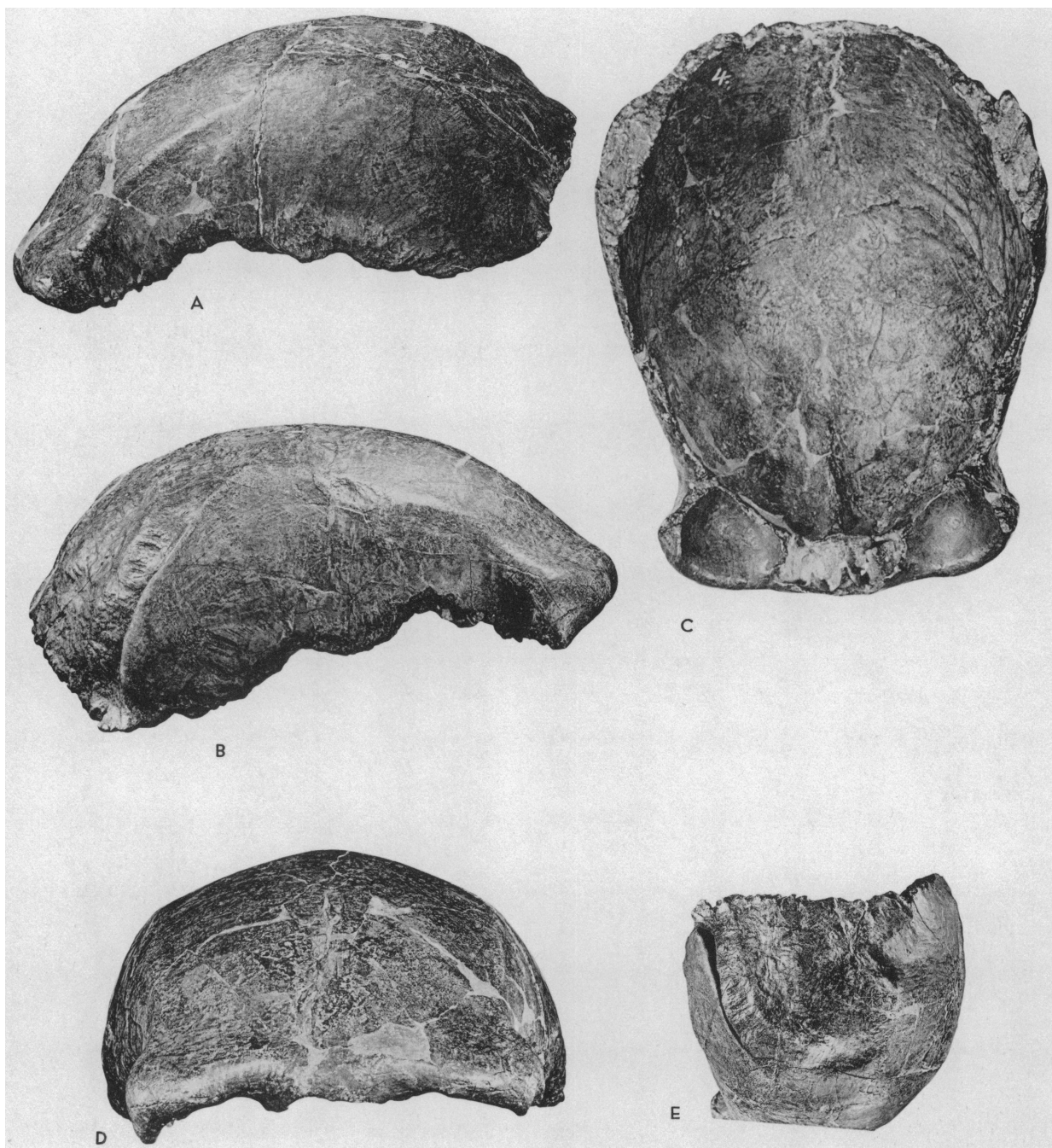
Solo Skull I



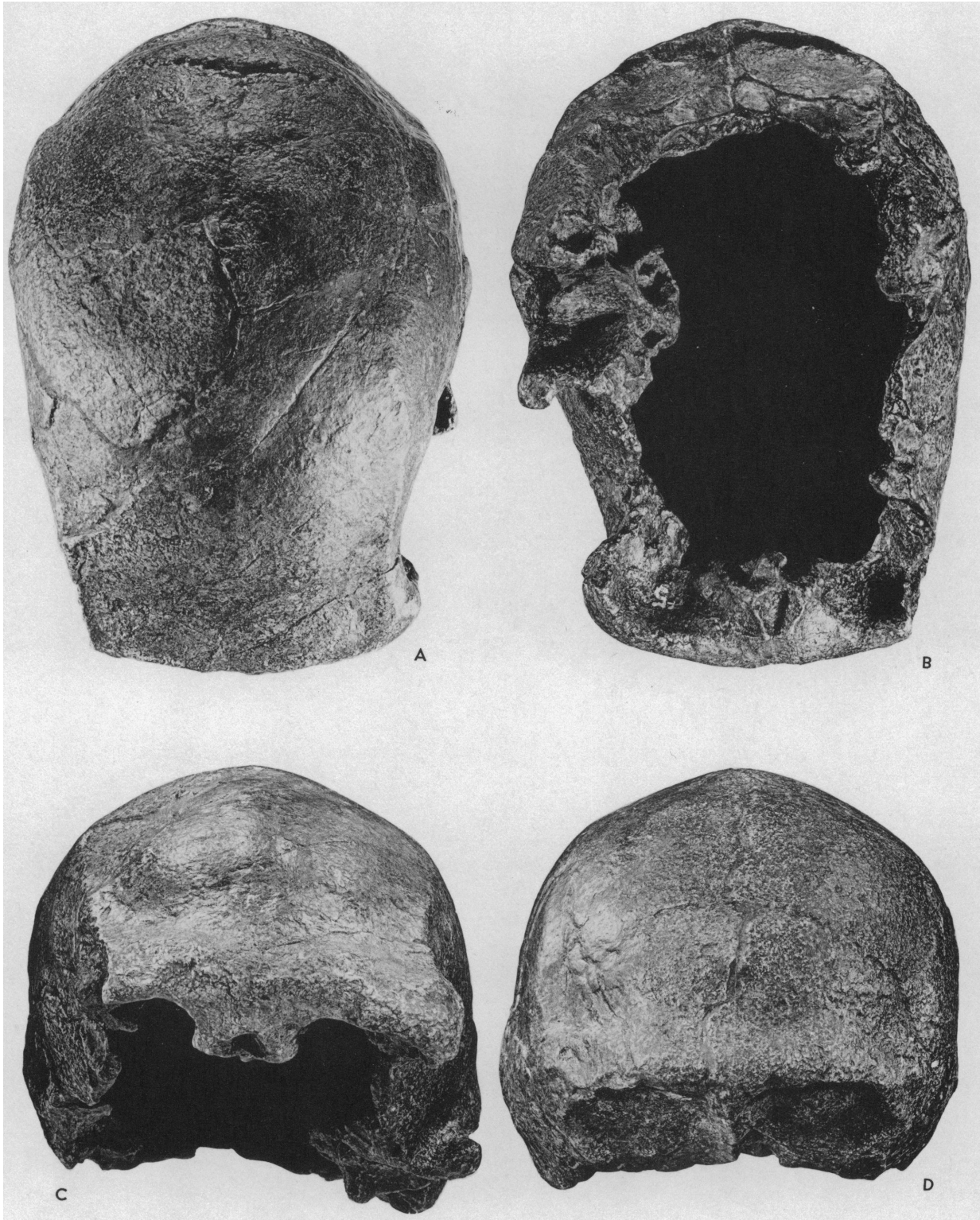
Solo Skulls I and II



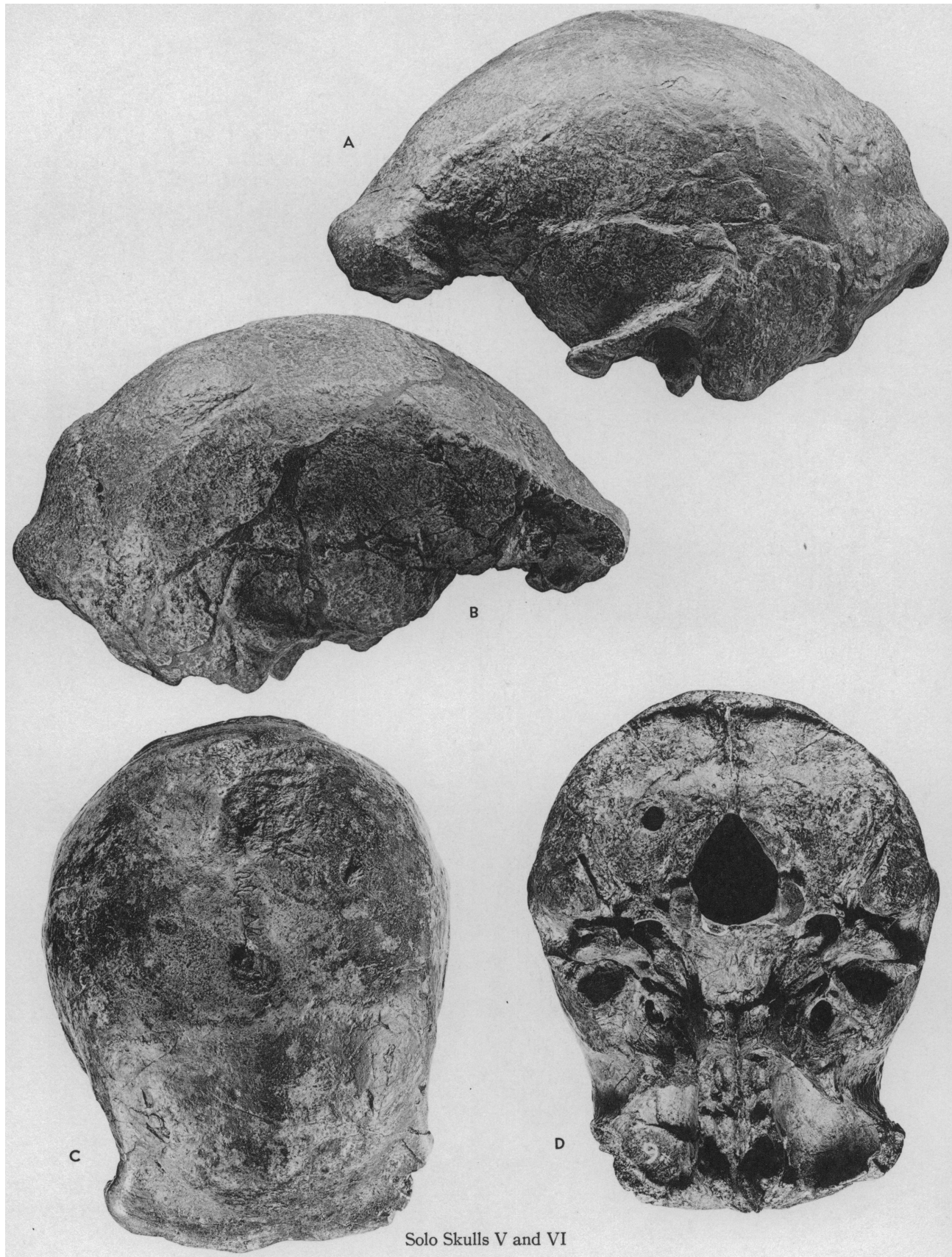
Solo Skulls III and IV



Solo Skull IV



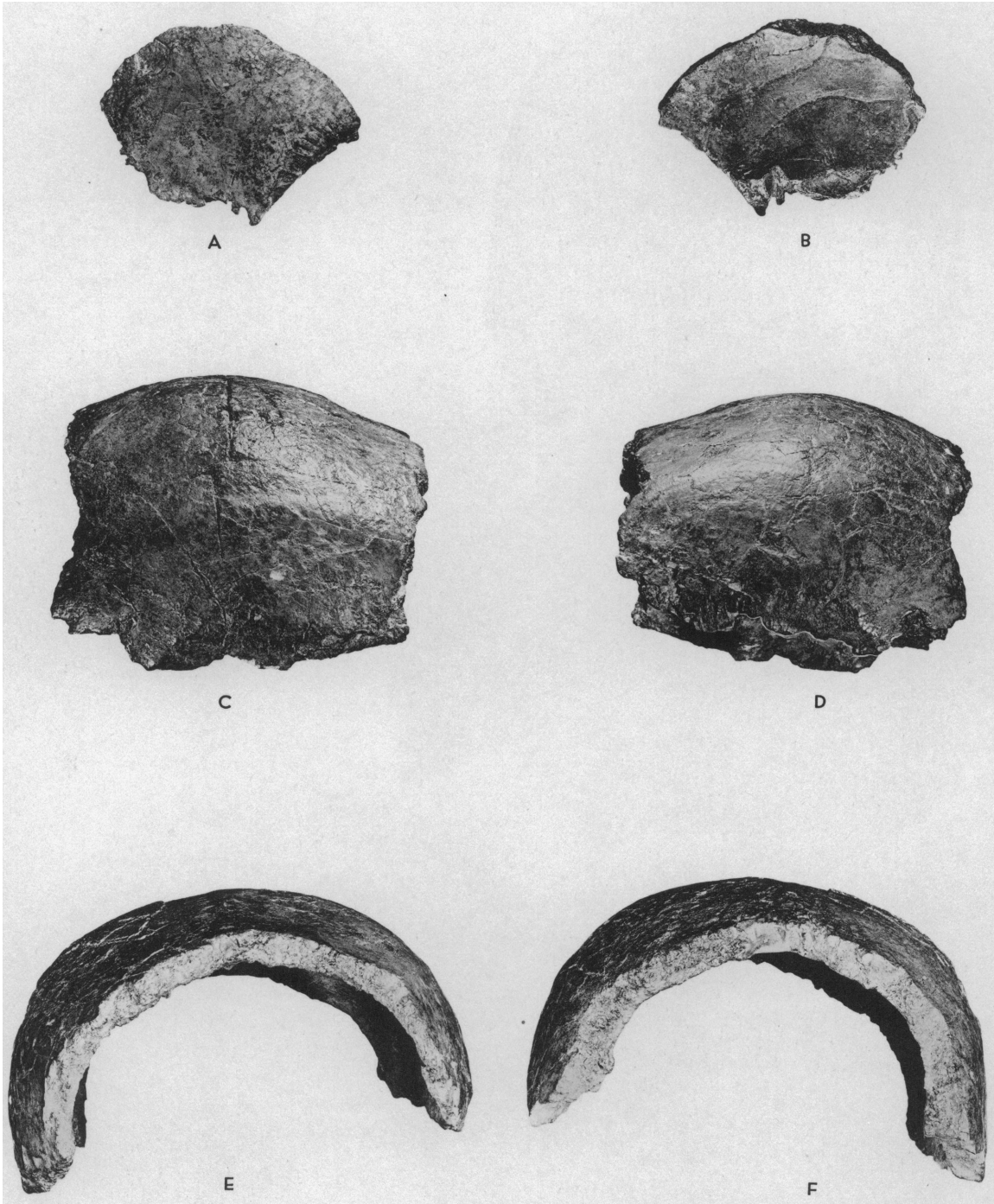
Solo Skull V



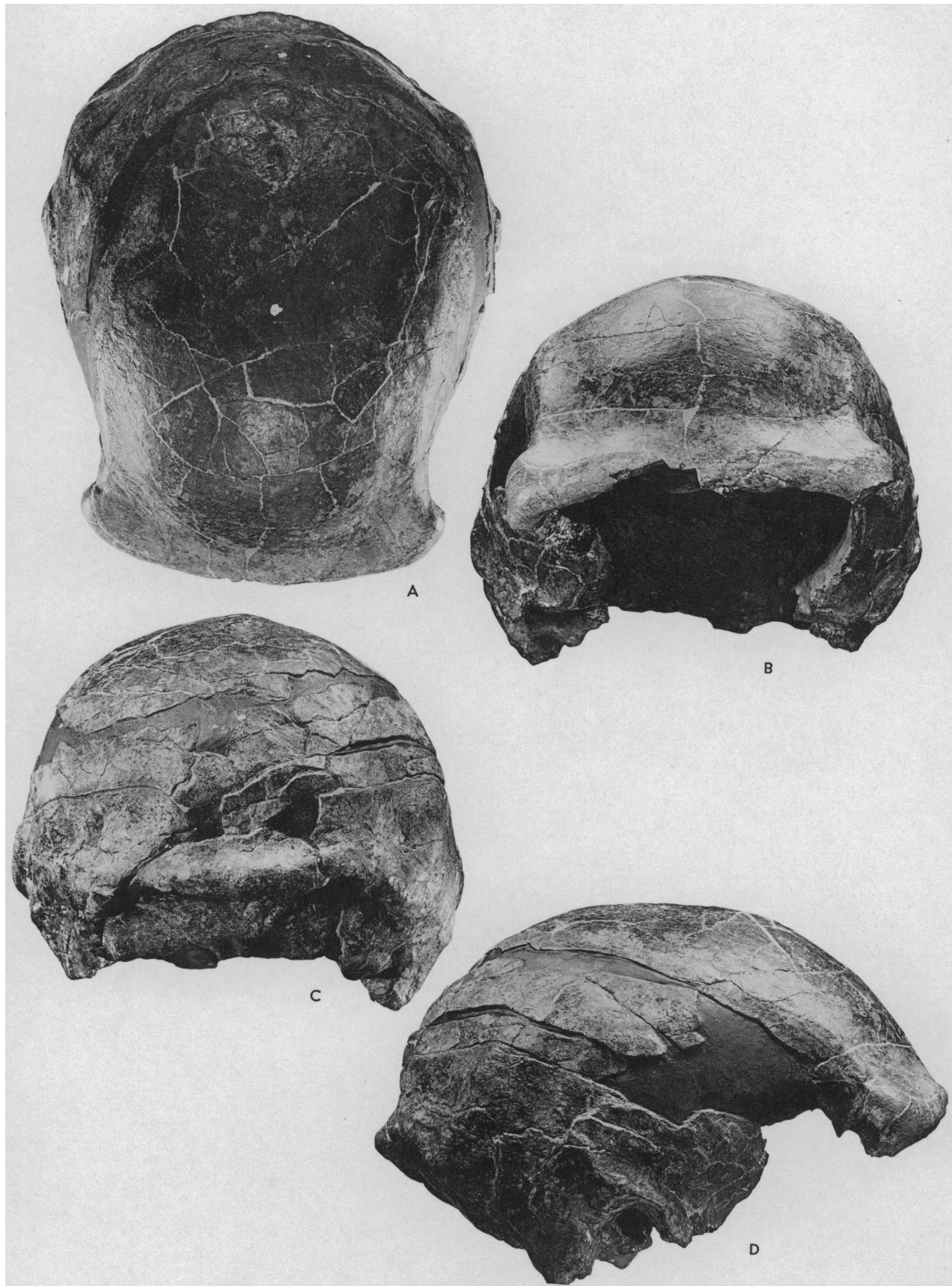
Solo Skulls V and VI



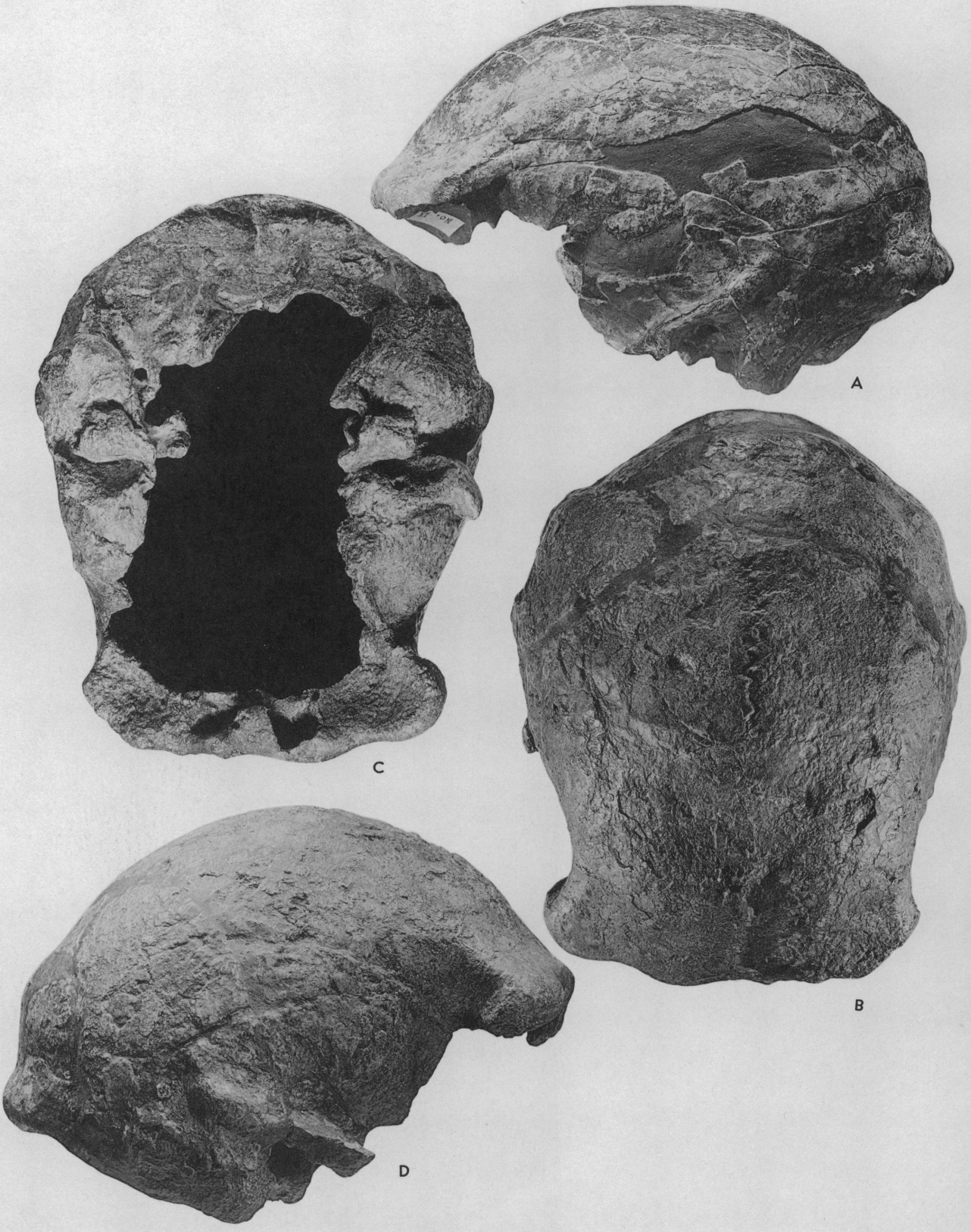
Solo Skull VI



Solo Skulls VII and VIII



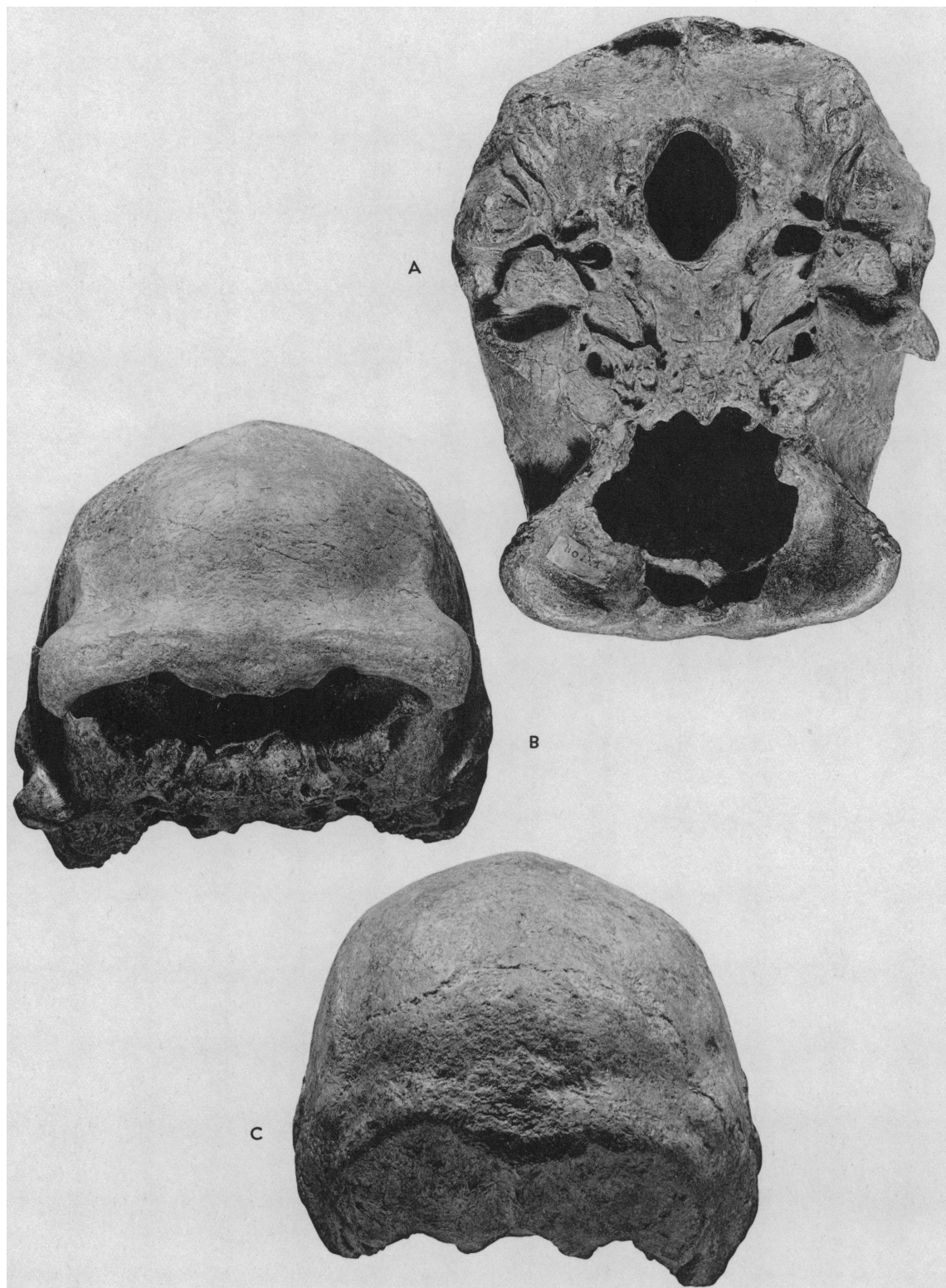
Solo Skull IX



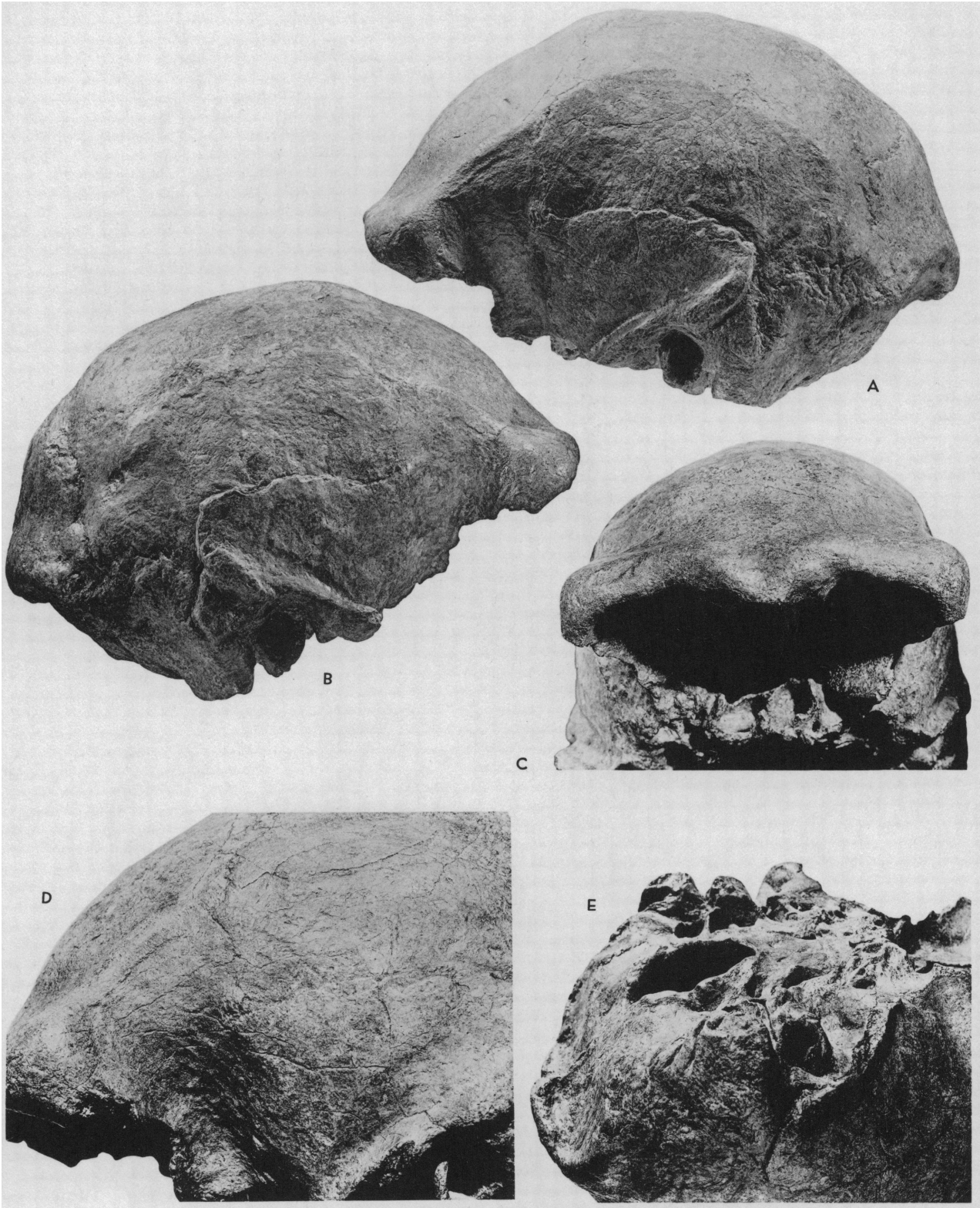
Solo Skulls IX and X



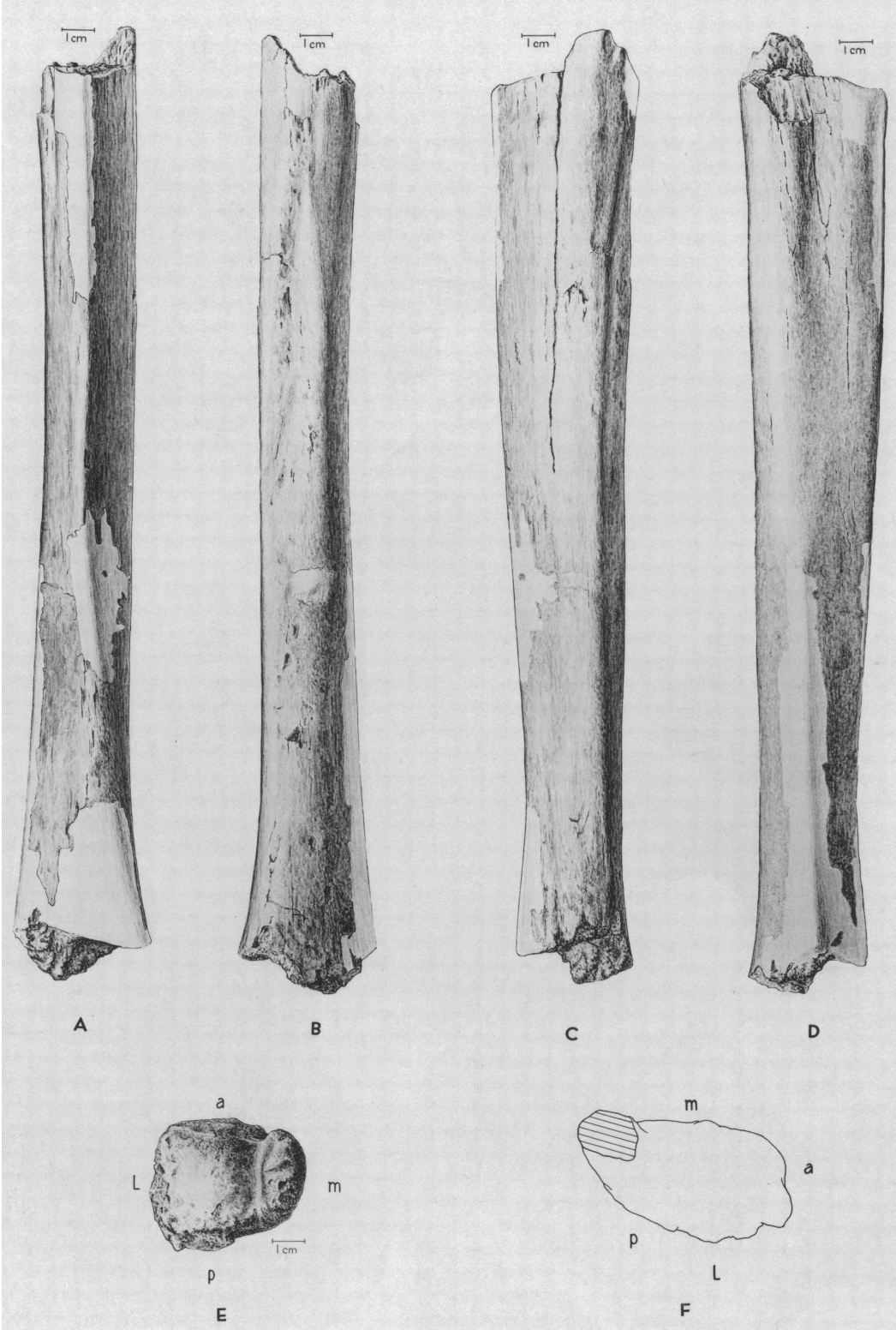
Solo Skulls X and XI



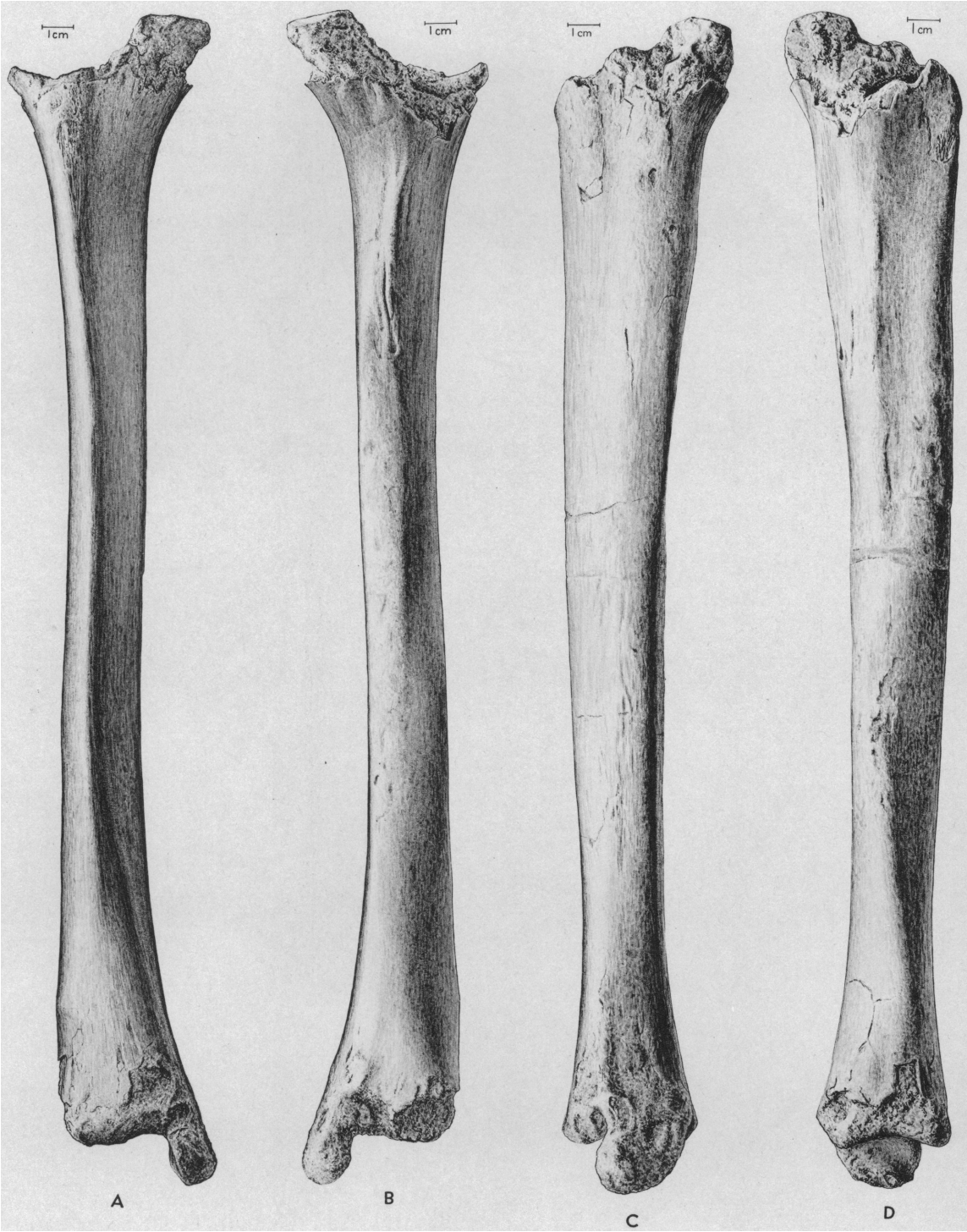
Solo Skull XI



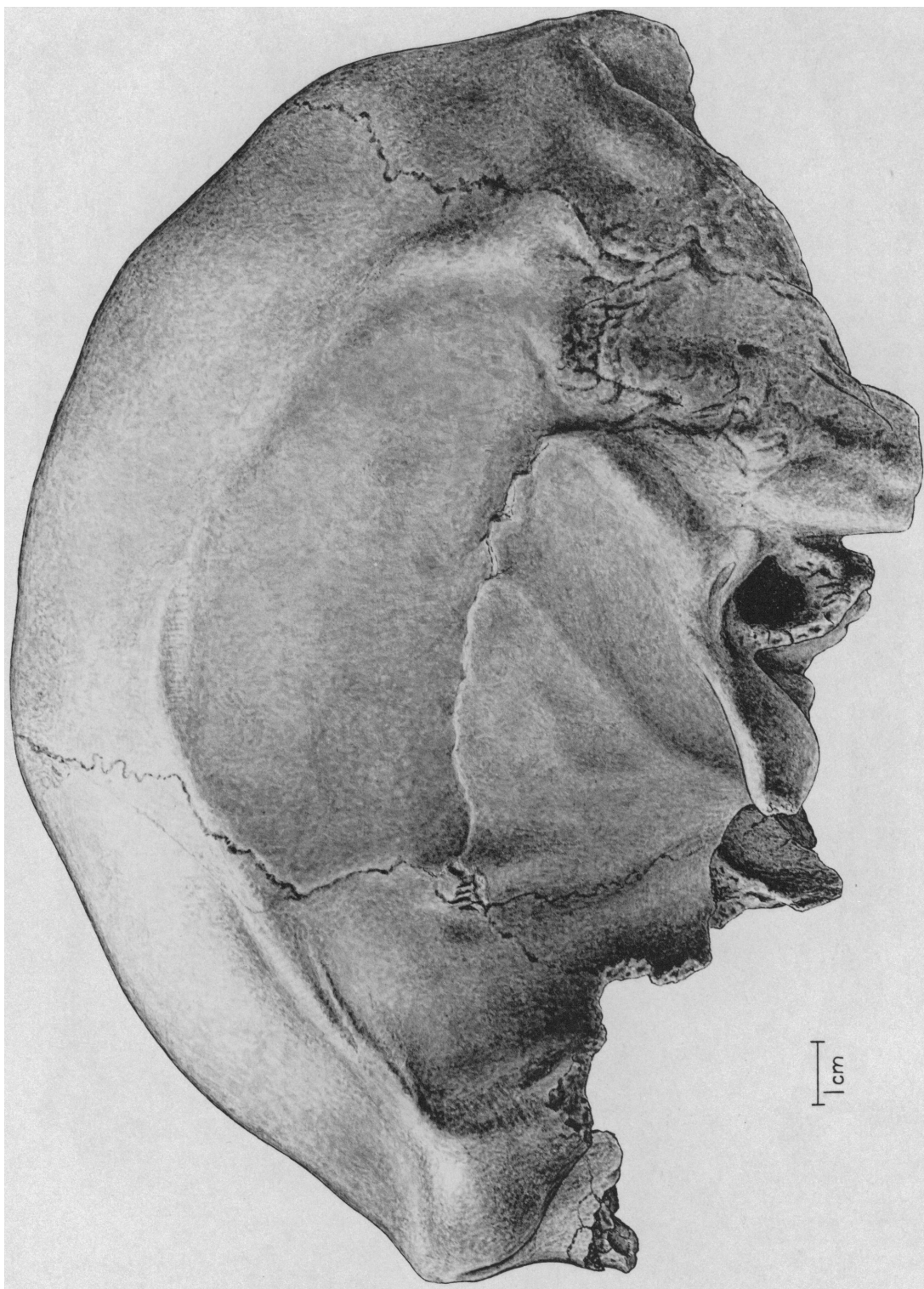
Solo Skull XI



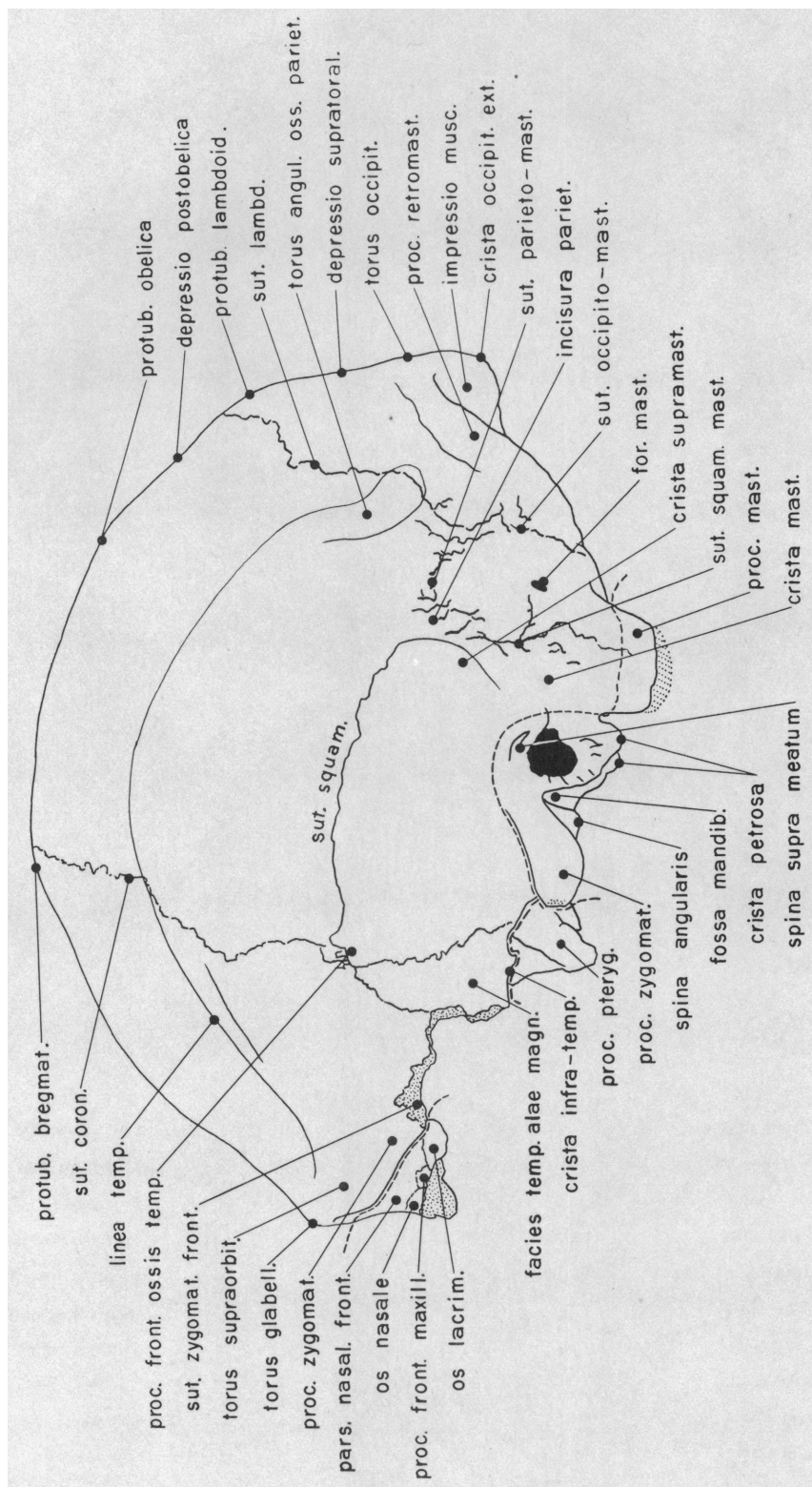
Solo Tibiae A and B



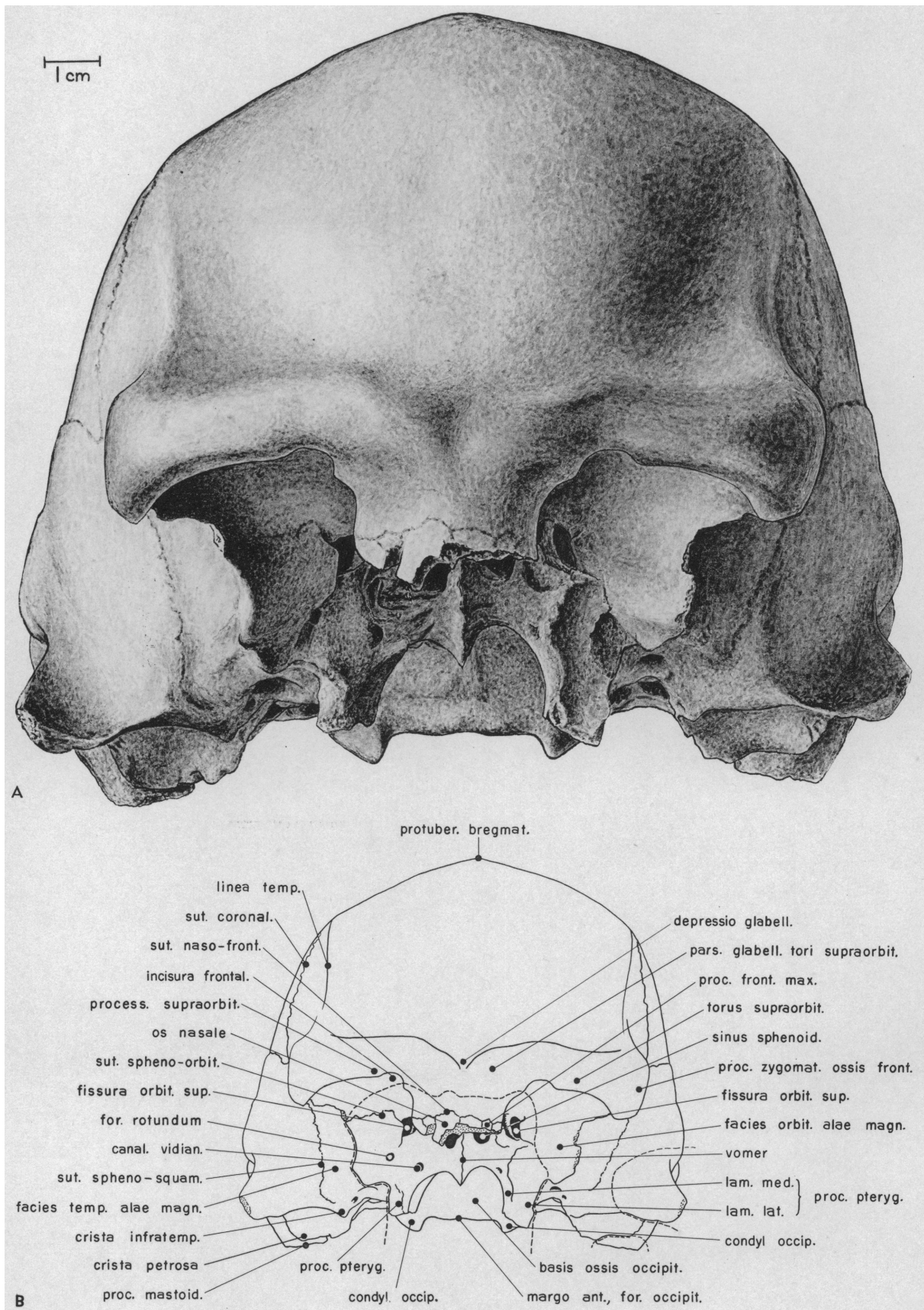
Solo Tibia B



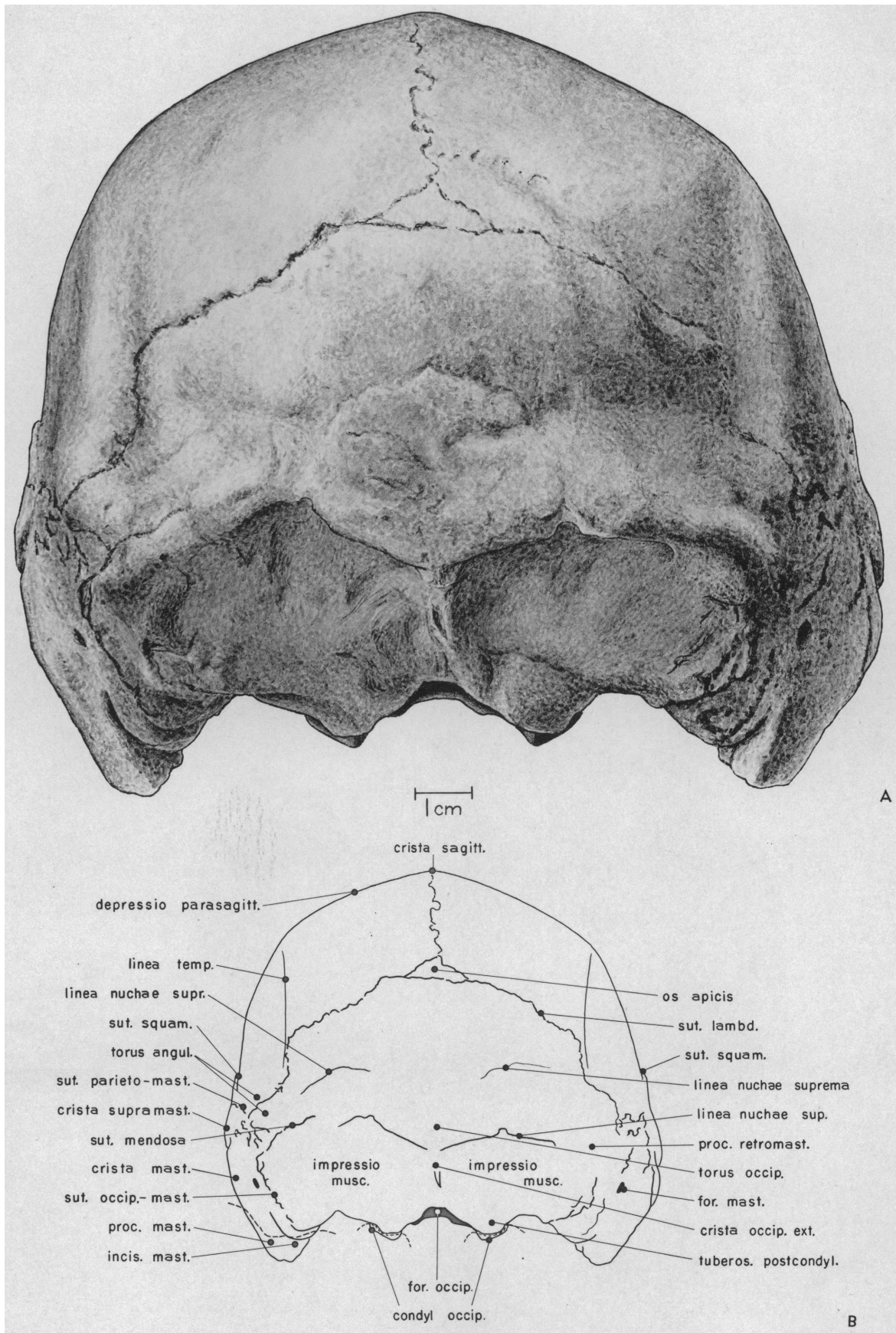
Solo Skull XI



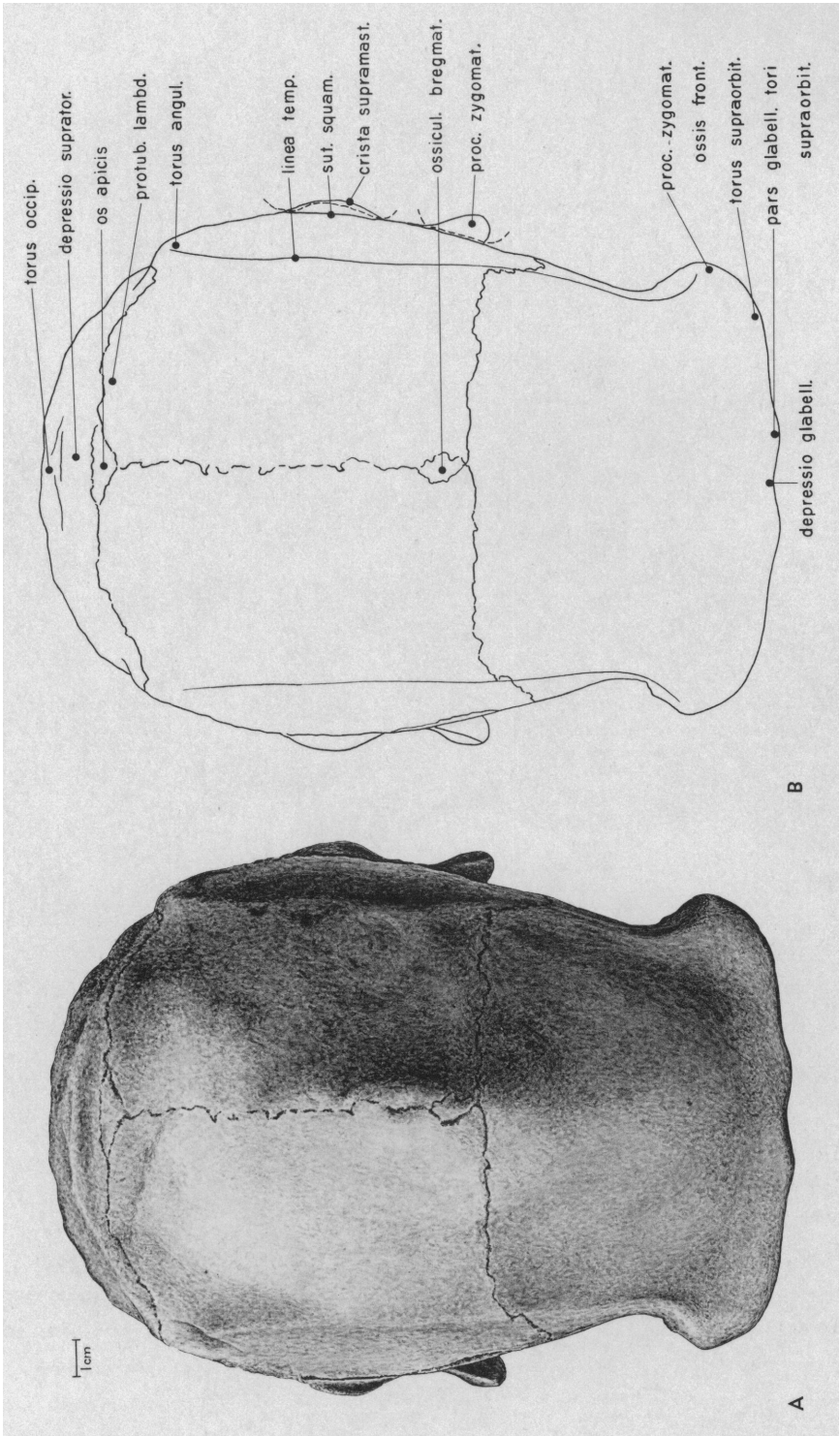
Solo Skull XI



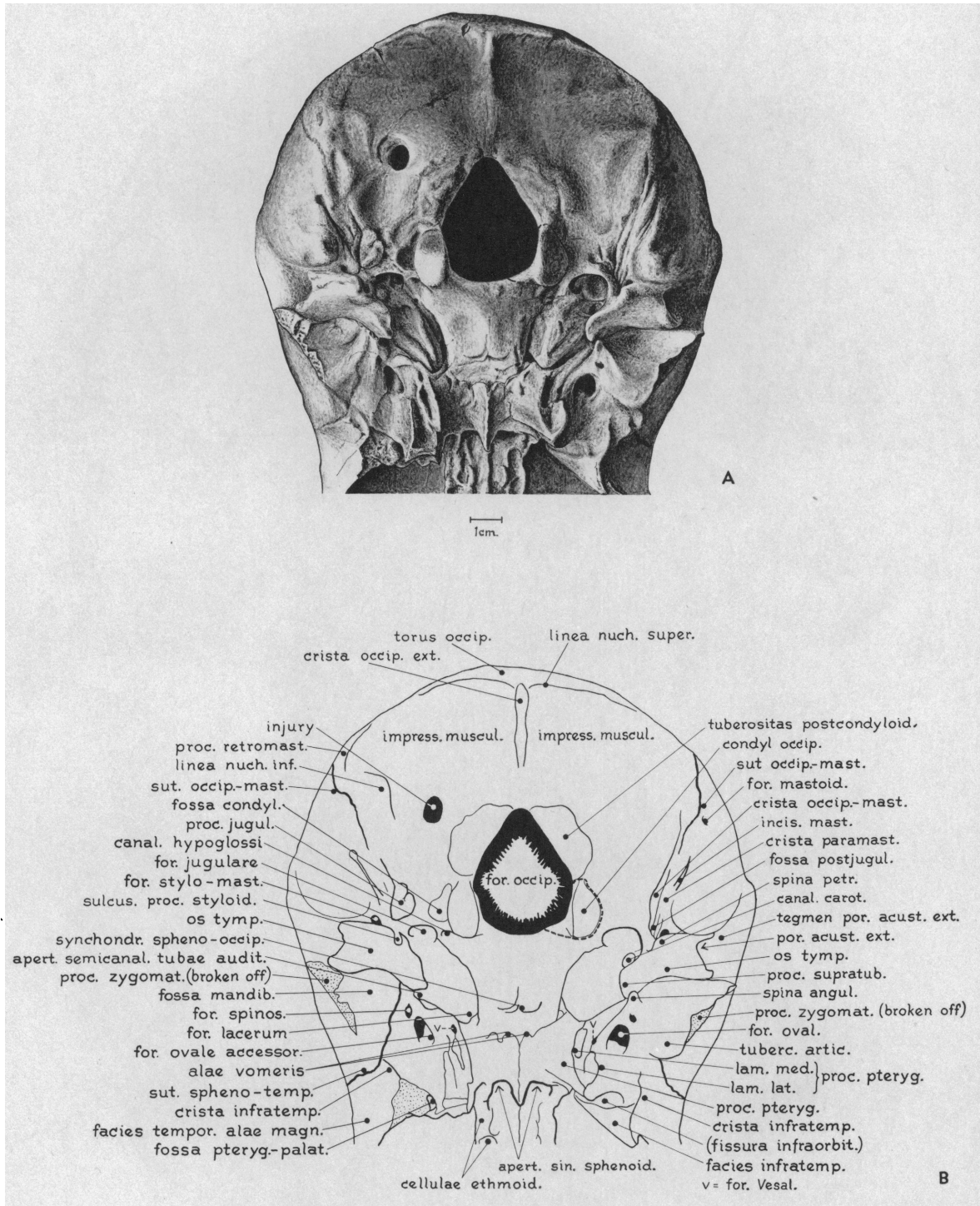
Solo Skull XI



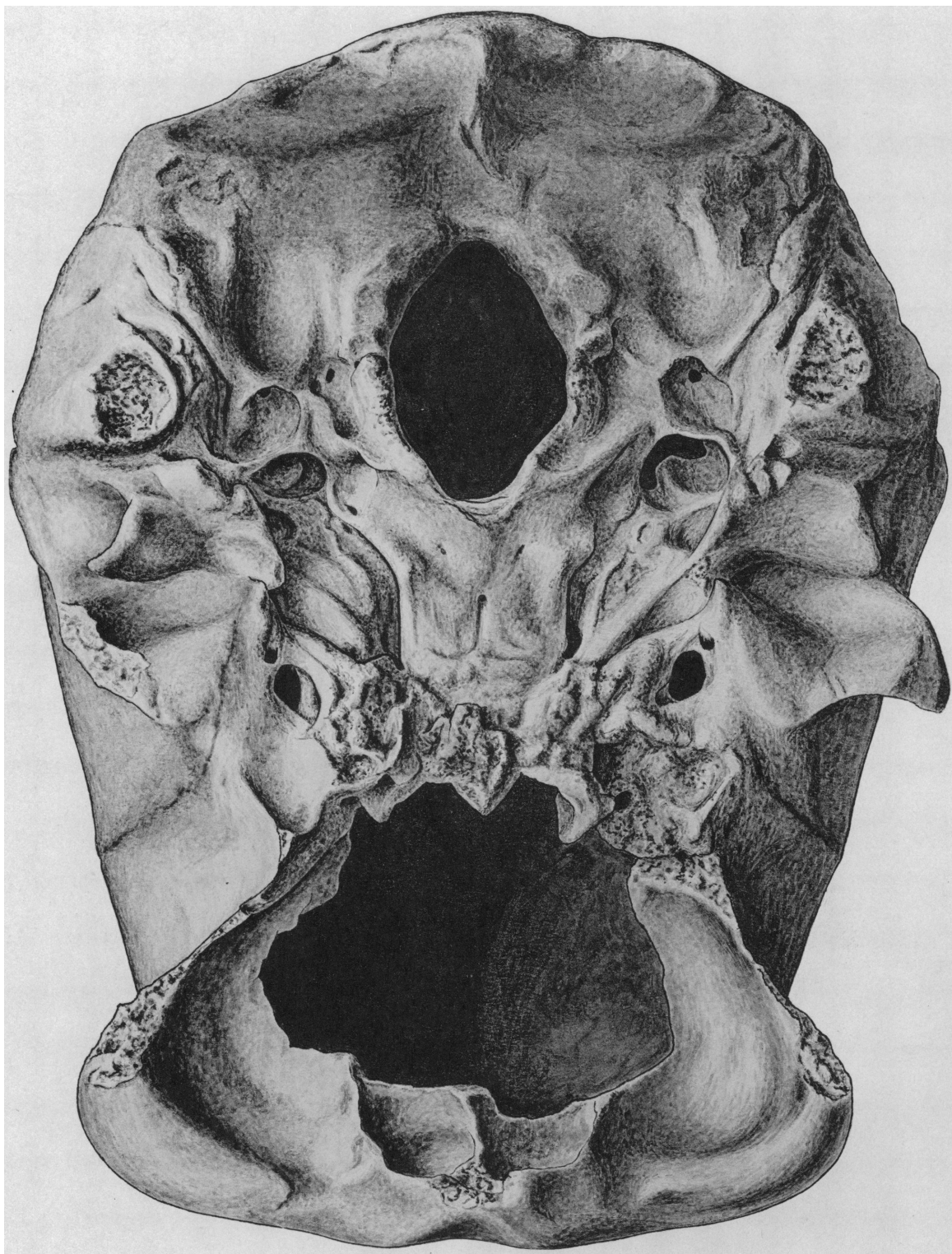
Solo Skull XI



Solo Skull XI

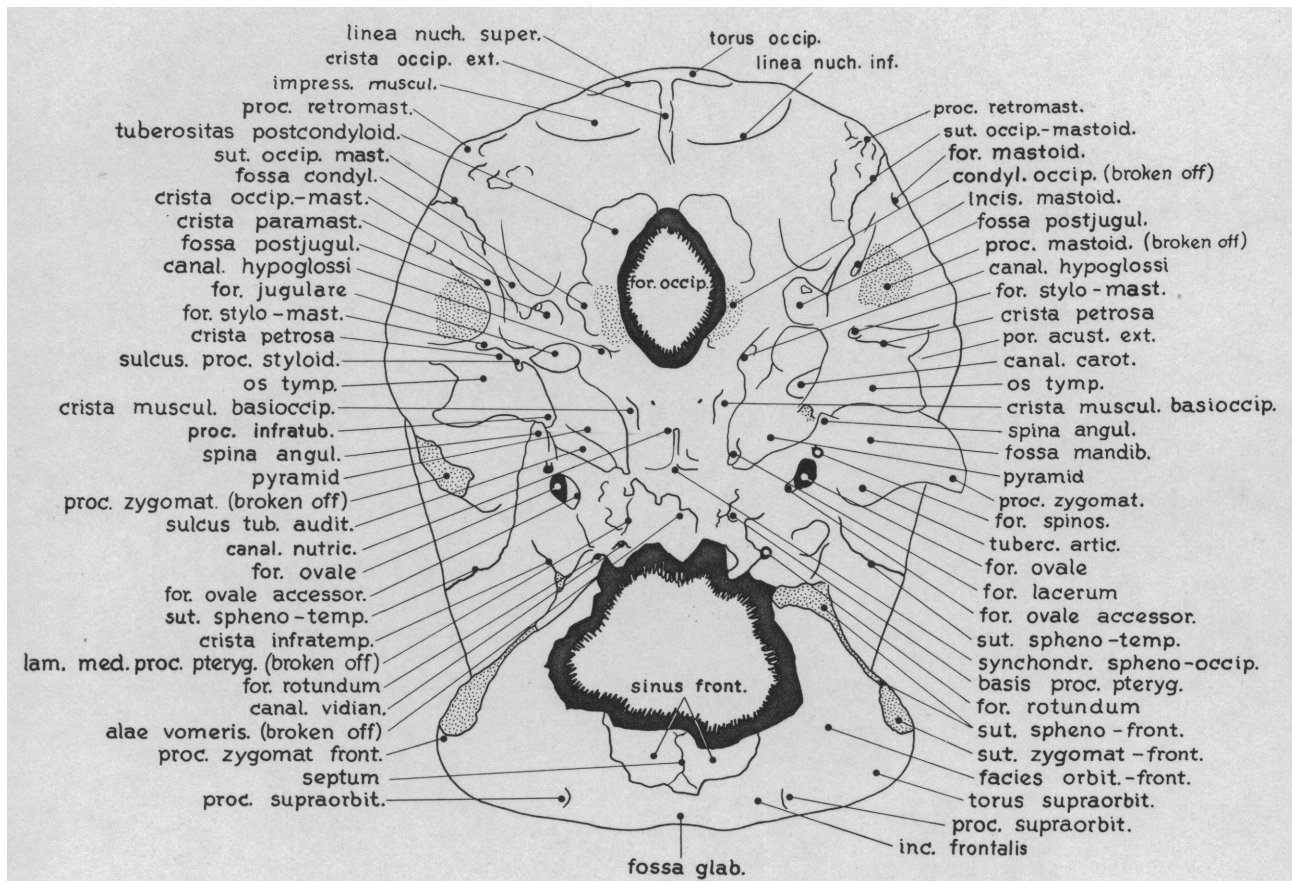


Solo Skull VI

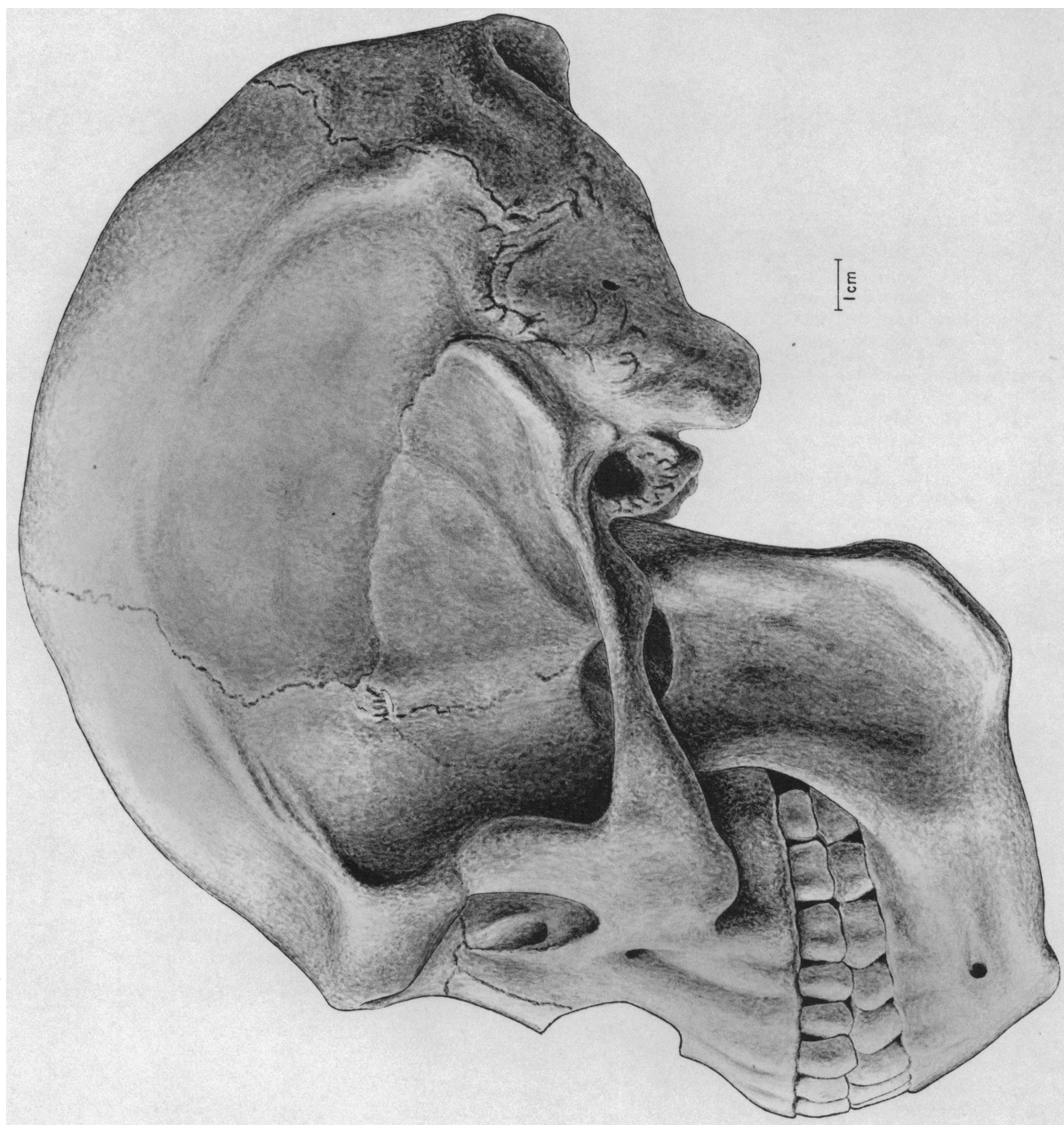


1 cm.

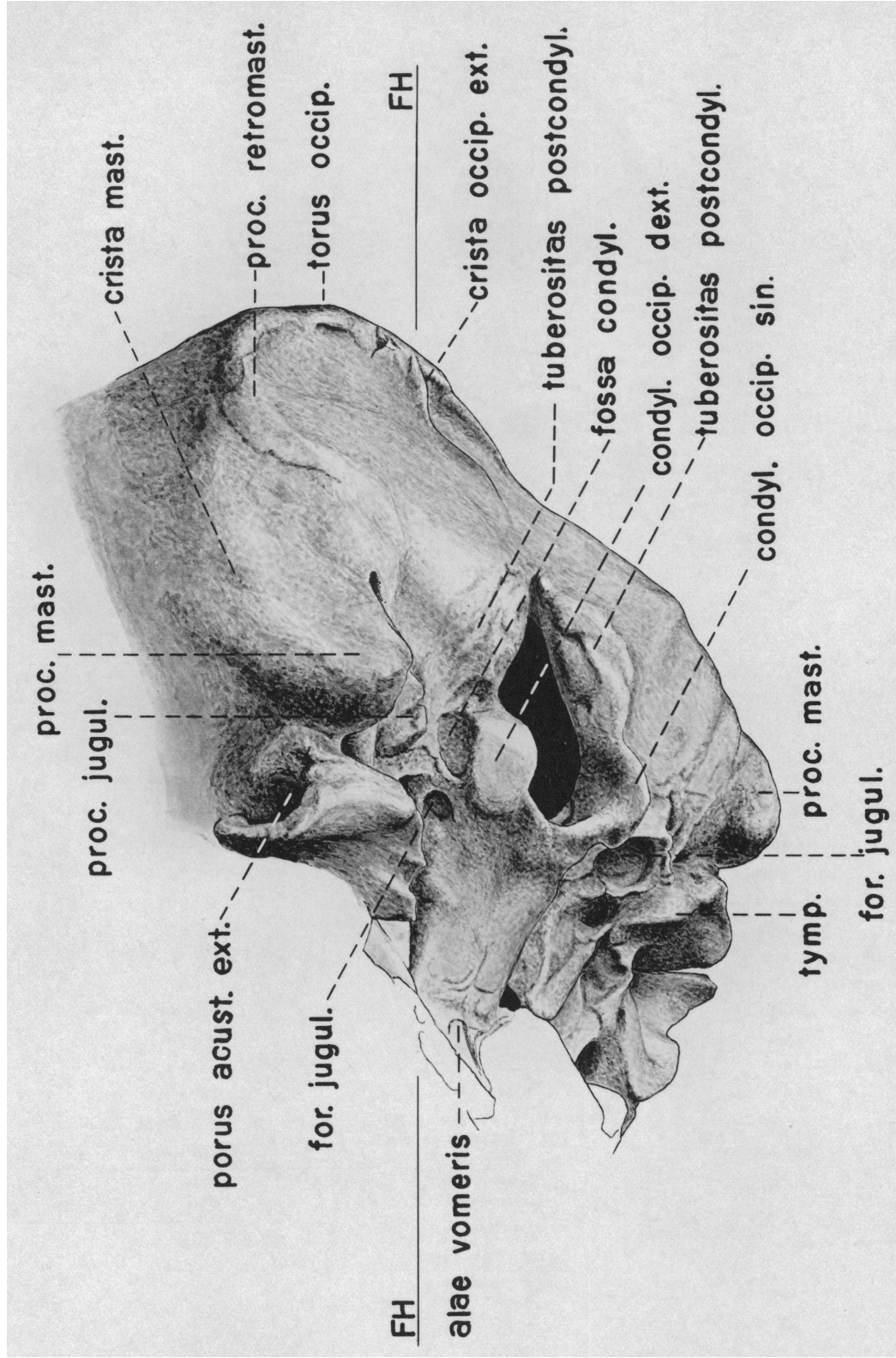
Solo Skull XI



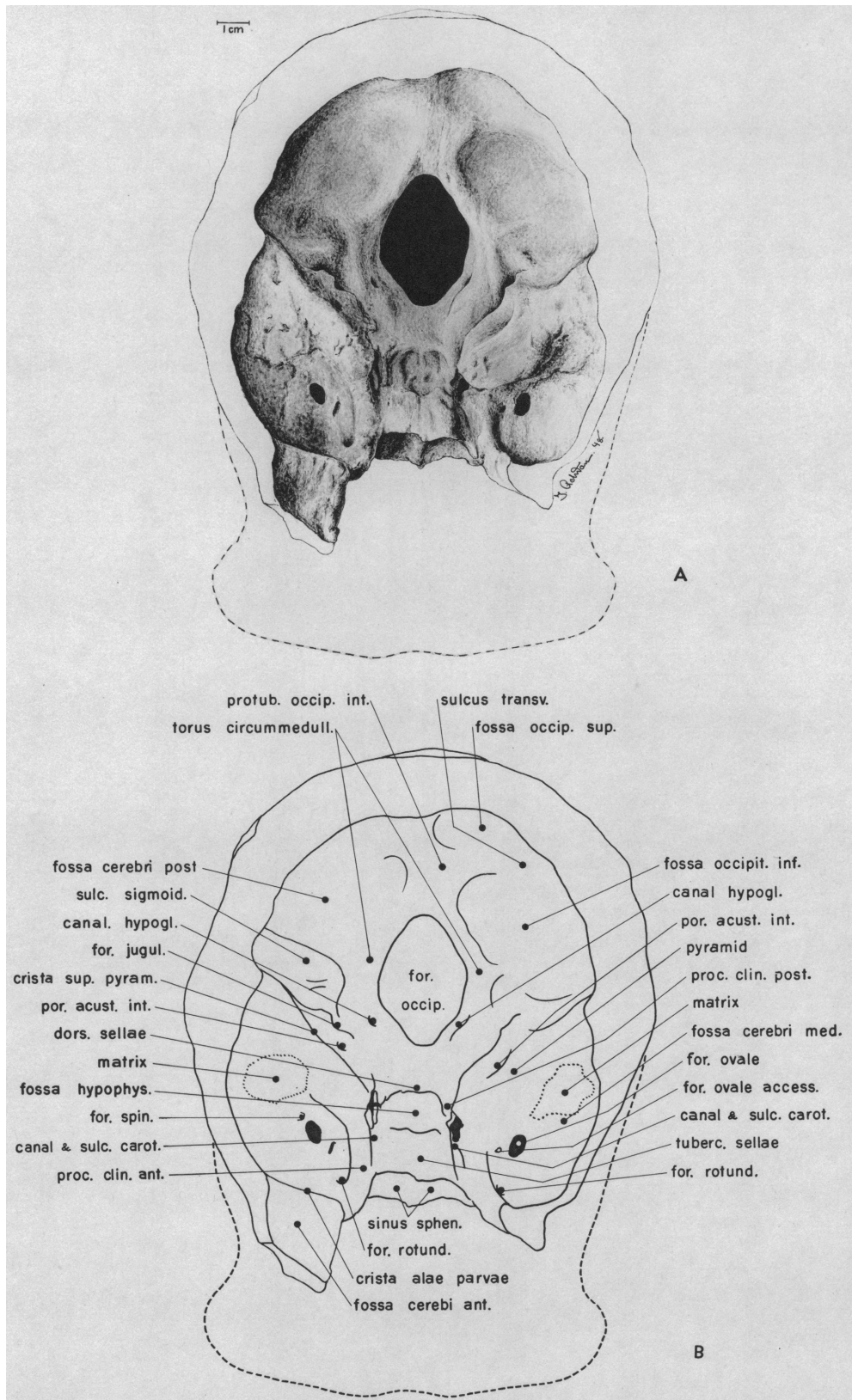
Solo Skull XI



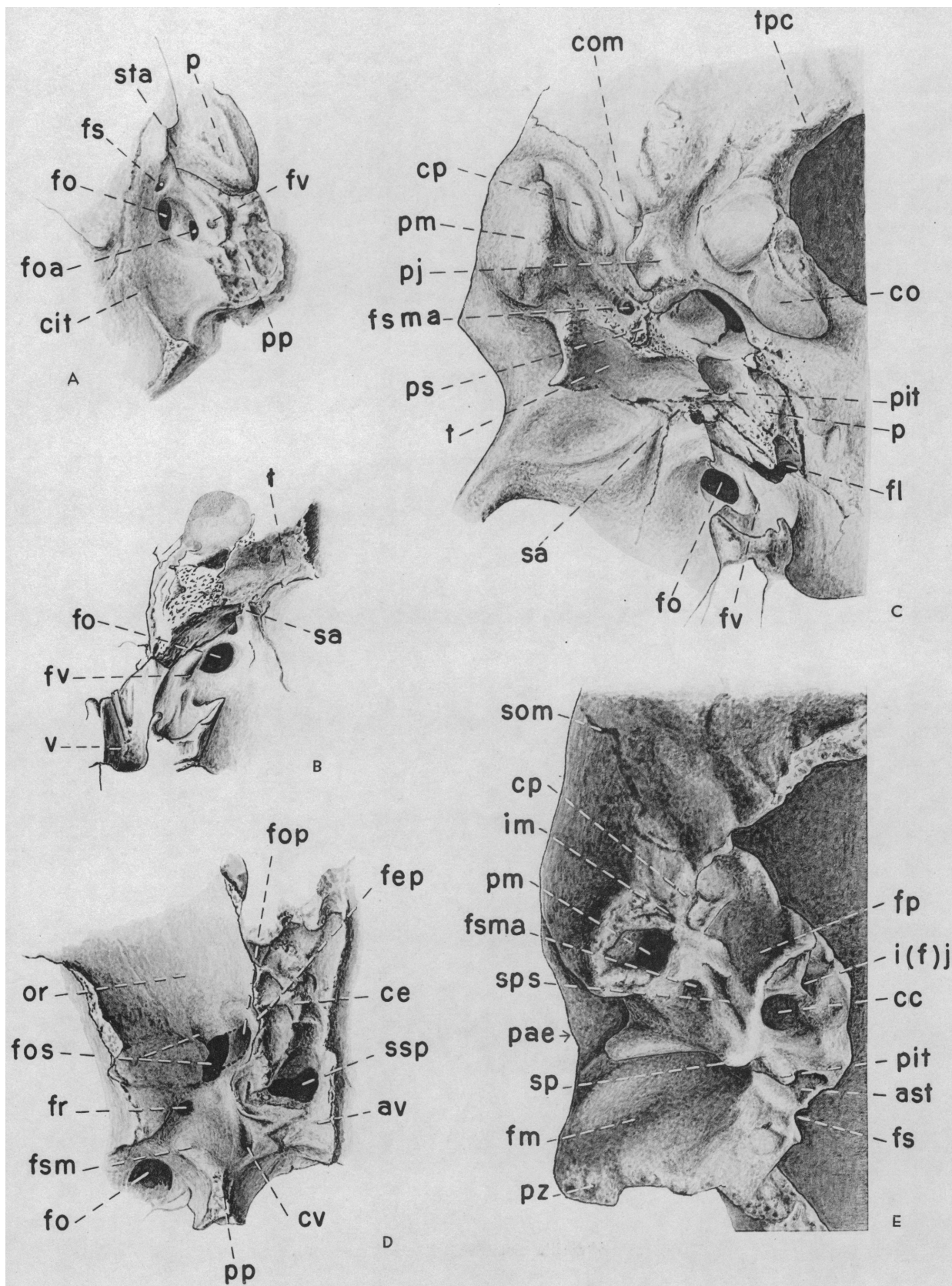
Reconstruction of skull of Solo man



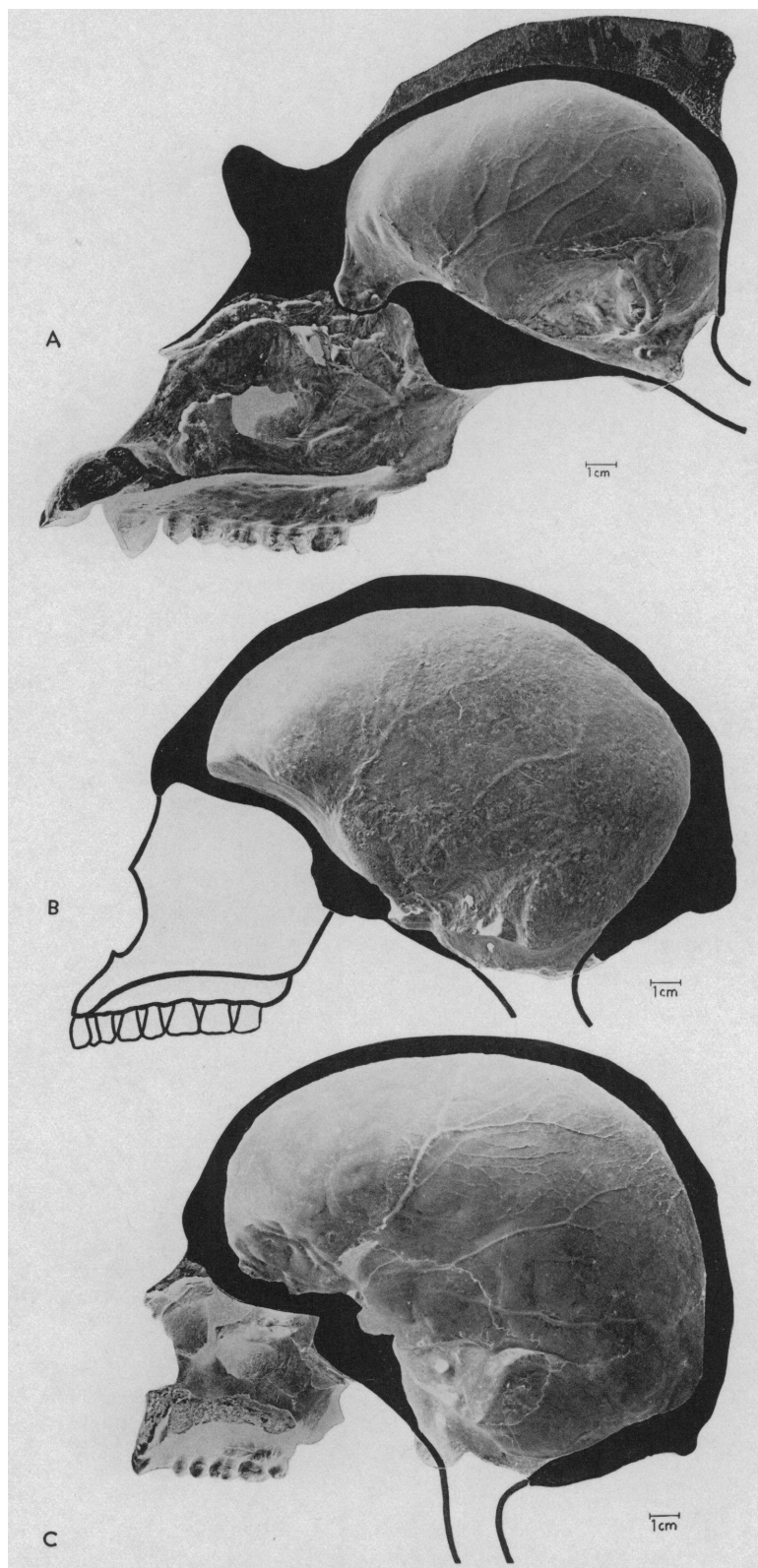
Solo Skull VI



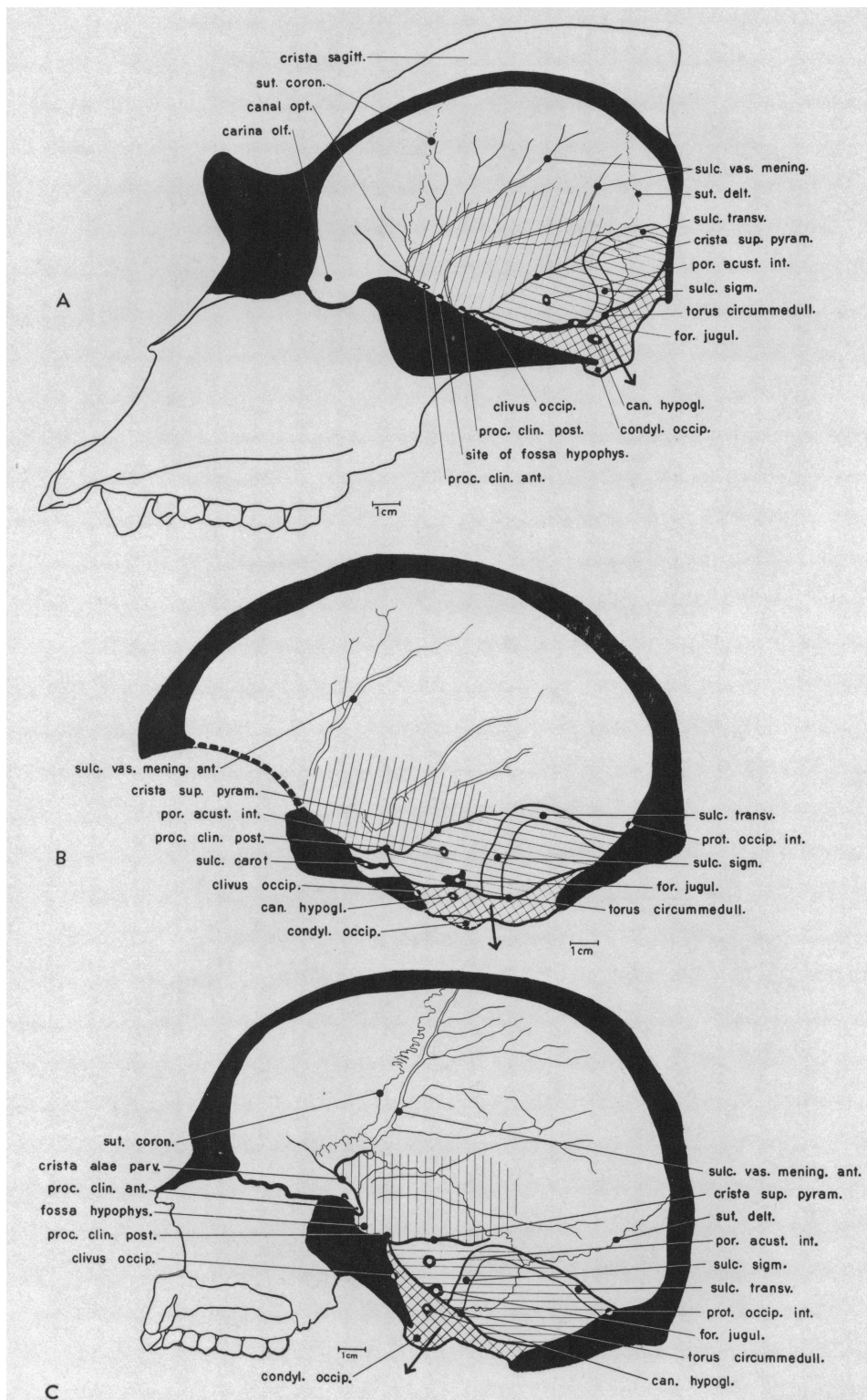
Solo Skull XI



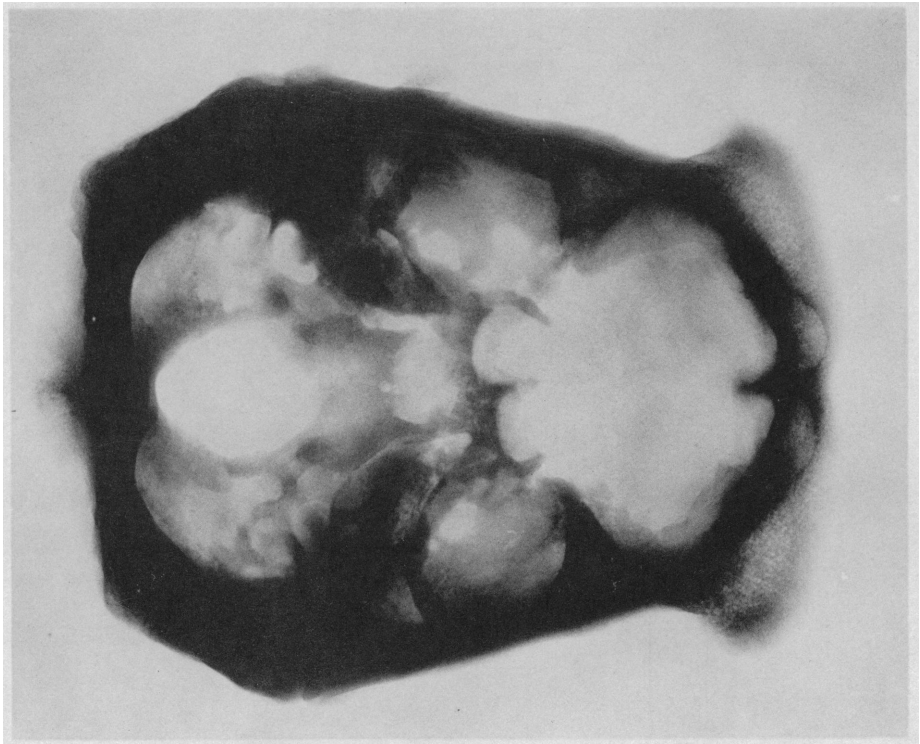
Solo Skull XI, Australian and Tasmanian skulls, Solo Skulls VI and V



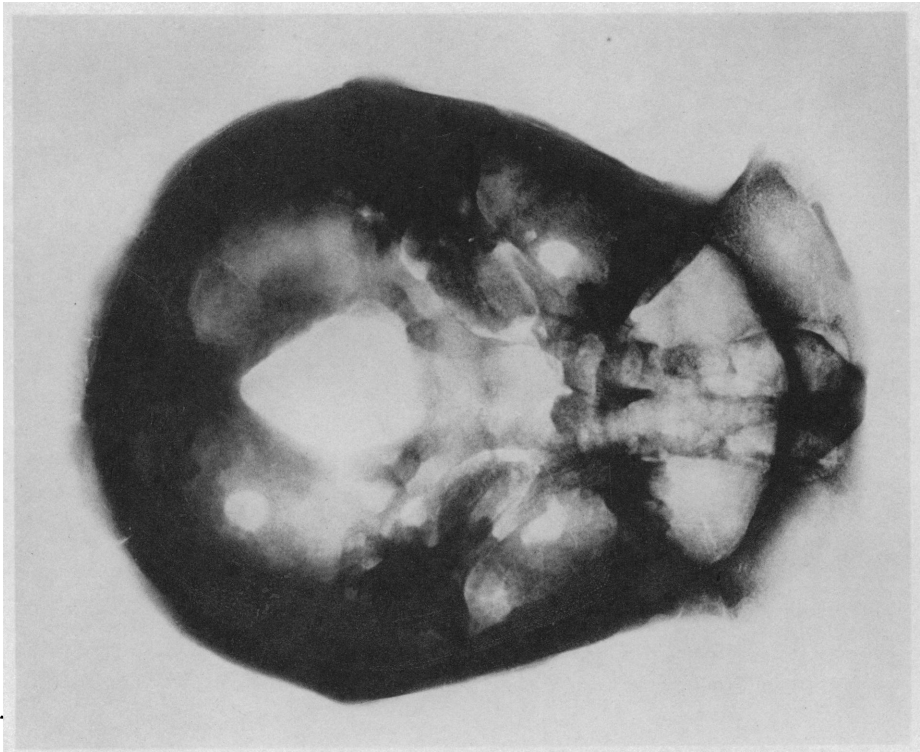
Endocasts of gorilla, Solo Skull XI, and modern man



Key to landmarks on endocasts of gorilla, Solo Skull XI, and modern man shown on Pl. 45



B



A

X-ray photographs of Solo Skulls VI and XI

ANTHROPOLOGICAL PAPERS
OF THE
AMERICAN MUSEUM OF NATURAL HISTORY

Volume 43

PART 1. Surface Survey of the Virú Valley, Peru. 1. Virú Valley: Background and Problems. By James Alfred Ford and Gordon R. Willey. 2. Cultural Dating of Prehistoric Sites in Virú Valley, Peru. By James Alfred Ford. Pp. 1-90, 7 plates, 9 text figures. Price \$1.50.

PART 2. The Archaeology of Coastal New York. By Carlyle Shreeve Smith. Pp. 91-200, 8 plates, 3 text figures, 5 tables. Price \$1.50.

PART 3. Morphology of Solo Man. By Franz Weidenreich. Introduction. By G. H. R. von Koenigswald. Pp. 201-290, 32 plates, 26 text figures, 14 tables. Price \$2.50.

PART 4. *In preparation.*