III. The Croonian Lecture.—*On the Discovery, Morphology, and Environment of* Sinanthropus pekinensis.

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(Read December 8, 1932.—Received June 27, 1933.)

[Plates 6–15.]

Contents.

Introduction.

During the interval which has elapsed since the subject-matter of this paper was presented in lecture form, a memoir has been completed by the Cenozoic Research Laboratory of the Geological Survey of China, on the subject of " Fossil Man in China " and ancillary problems of Cenozoic research in that area (Black and others, 1933). By reason of this fortunate circumstance it has become possible to incorporate in the present communication a résumé of the chief geological, palæontological, and archæological conclusions to which we have been led as a result of the completion to its present stage of that wider study.

It is a pleasure to acknowledge here my indebtedness to my friends and colleagues of the staff of the Cenozoic Research Laboratory, without whose cordial co-operation and assistance the present paper could not have been written. To my friends Dr. V. K. Ting, Honorary Director of Cenozoic Research in China, and Dr. Wong Wen Hao, Director of the Geological Survey of China, I wish also to express again my most hearty thanks for their unfailing help and support throughout the whole course of my work in China. I wish further to thank Dr. Wong for permission to use here, in modified form, a number of illustrations which have appeared earlier in publications either of the Geological Survey, or of the Geological Society, of China.

The general physiography and location of the Choukoutien area is admirably illustrated in Professor G. B. Barbour's two block diagrams, figs. 1 and 2, and in the three field sketches by the same artist of the immediate Choukoutien terrain, here reproduced in fig. 3. I am much indebted to Professor Barbour for his kindness in preparing and permitting me to use these instructive and artistic illustrations.

The village of Choukoutien* is situated at the foot of the Western Hills on the border of the Hopei plain 42 kilometres to the south-west of Peking, though by road its distance from the latter city is somewhat over forty miles (*cf.*, fig. 28). A branch line connects Choukoutien with Liuliho junction on the Peking-Hankow railway. When the latter, then known as the Liukochiao-Hankow railway, was under construction in 1898, the Choukoutien branch was built to tap the natural resources of that area for construction

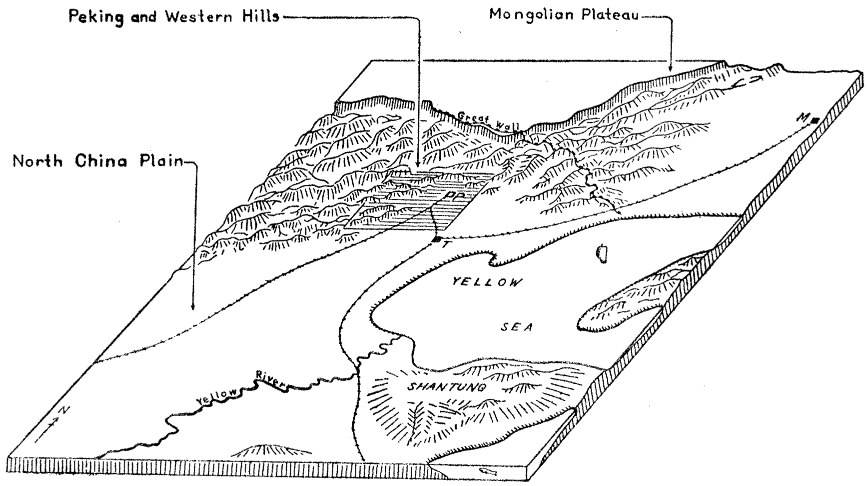


FIG. 1.—Block diagram of North China region, after Professor G. B. BARBOUR, to illustrate the general relations of the Peking and Western Hills area (horizontal-lined square). P, Peking (Peiping); T, Tientsin; M, Moukden.

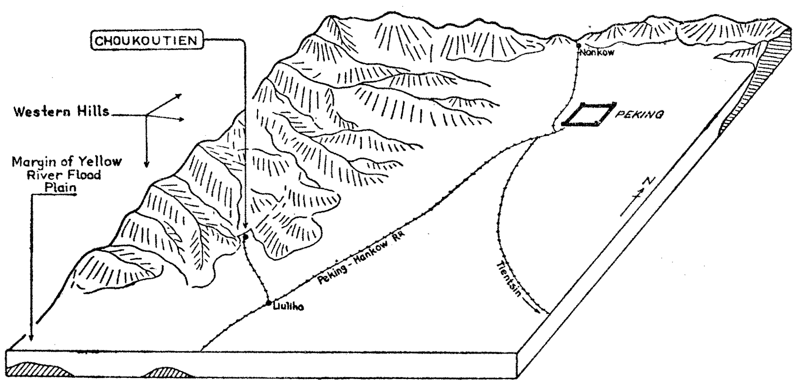


FIG. 2.—Block diagram of Peking-Western Hills area, after Professor G. B. BARBOUR.

materials. The main line from Hankow was extended to Peking in 1901 and from that date onward the Choukoutien area has increased in economic importance, a large part of the lime and granite used in the metropolitan district being derived from Choukoutien quarries.

* The Romanization *Choukoutien*, in one word and without aspirates, is the official one adopted by the Geological Survey of China in conformity with long-established usage by the Chinese Postal Service.

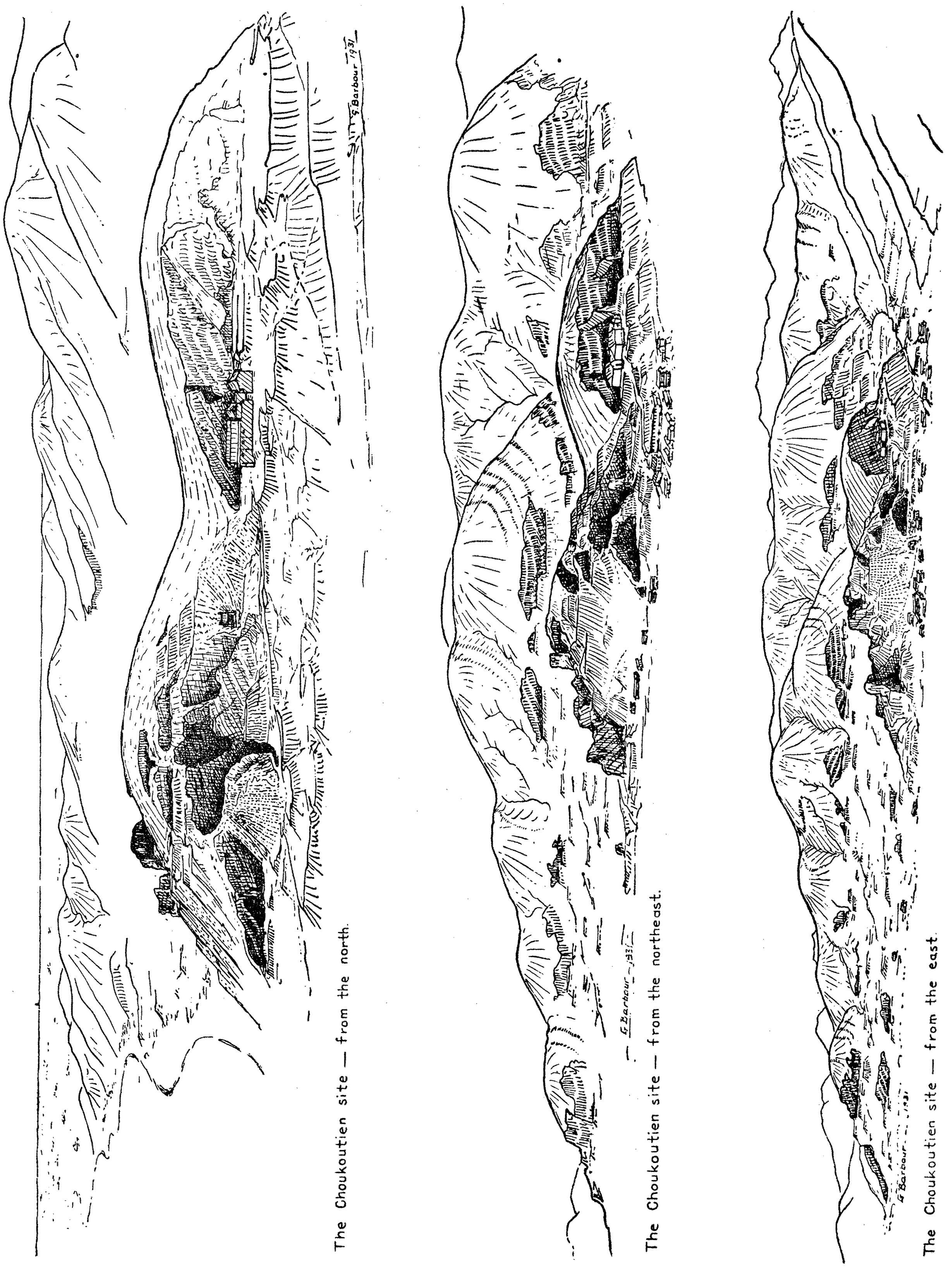


FIG. 3.—Three field sketches made in 1931 by Professor G. B. BARBOUR illustrating the Choukoutien terrain. (*See* text; *cf.* Plates 1 and 2.)

History of the Discovery and Progress of Excavations.

Discovery.

In the spring of 1918 Dr. J. G. Andersson, at that time Mining Adviser to the Chinese Government, visited Choukoutien and had his attention drawn to a peculiar pillar-like fossiliferous deposit, known locally as Chikushan, which was exposed in a limestone quarry. On examination it was clear that the pillar represented the remains of a fissure deposit exposed by the removal of the surrounding limestone. Subsequently this deposit was briefly described by Dr. Andersson (1919) who noted the apparently quite modern type of the numerous small bird and mammal bones recovered, and considered the deposit to be post-Loessic in age.

The Chikushan locality was again visited in the summer of 1921 by Dr. Andersson, accompanied by Drs. Walter Granger and Otto Zdansky. On this occasion conversation with local quarrymen led to the discovery of a larger and more richly fossiliferous deposit a short distance to the north-west of the Choukoutien railway station. This deposit then became known as Locality 53 of Dr. Andersson's field notes and subsequently as our Choukoutien Locality 1 (*Sinanthropus* site).

At the time of its discovery, the deposit of Locality 1 had been partially exposed at the head of an abandoned quarry on the north side of a small outlying foothill of Ordovician limestone. To the north of this hill lies the valley of Laoniuko which in turn on its north is bordered by hills formed of Carboniferous slates and shales (fig. 31). These geological facts were well known to Dr. Andersson, and during his examination of the talus of loose material fallen into the quarry from the face of the deposit he was surprised to notice in it some fragments of white quartz, a mineral normally foreign in that locality. The possible significance of this occurrence immediately suggested itself to him, and turning to his companions he exclaimed, dramatically, " Here is primitive man, now all we have to do is to find him ! "

For some weeks in the summer of 1921, and again for a longer period in 1923, Dr. Zdansky carried on palæontological excavations of this cave deposit. He accumulated an extensive collection of fossil material which was subsequently prepared and studied in Professor Wiman's laboratory in Uppsala. The results of these important studies have already in large part been published (Zdansky, 1928).

While excavating in 1923, Dr. Zdansky recovered from the Choukoutien cave deposit a worn and fossilized hominid molar tooth which he recognized at the time of its discovery as being anthropomorphic (Zdansky, 1928, p. 141). Later, among the material sent to Uppsala for preparation, a second hominid tooth, an unerupted lower permanent premolar, was recognized. Announcement of these startling discoveries was first made by Dr. Andersson on October 22, 1926, at a scientific meeting held in Peking in honour of H.R.H. The Crown Prince of Sweden then visiting the city.

Excavations, 1927–28.

As a result of the keen interest aroused by Dr. ANDERSSON'S announcement, the Geological Survey of China, in co-operation with the Department of Anatomy of the Peking Union Medical College, and supported by a grant from the Rockefeller Foundation, organized a research programme for a two-year intensive investigation of the Choukoutien cave deposit from which Dr. ZDANSKY'S material had been derived.

In the spring of 1927 Dr. BIRGER BOHLIN, whose work on the fossil Giraffidæ of China had just been completed in Dr. WIMAN'S laboratory, was engaged for a two-year period to take charge of the field palæontological work. At the same time Mr. C. LI was appointed for one season to act as official representative in the field of the Geological Survey of China and to carry on geological and topographical observations on the site.

Work was begun at Choukoutien in April, it being then considered possible that the whole site could be excavated during one field season. Before work was interrupted by the summer rains it became evident that the fossiliferous deposit was a much more extensive one than had at first been supposed, and by the end of the first year in the field it was recognized that at least another season's work would be necessary before the excavation could be finished. In spite of the difficulties encountered, Dr. BOHLIN worked on with enthusiasm and, three days before the excavation work was stopped, himself recovered the beautifully preserved left lower molar tooth upon the morphological characters of which it became subsequently possible to distinguish the generic status of *Sinanthropus* (BLACK, 1927).

Work was resumed at Choukoutien in April, 1928, Dr. BOHLIN being joined in the field by Dr. C. C. YOUNG and Mr. W. C. PEI, Dr. YOUNG replacing Mr. LI as official field representative of the Geological Survey. During the season's work numerous additional isolated teeth of *Sinanthropus* were recovered, together with the greater part of a juvenile jaw specimen of that form (Locus B jaw, *vide infra*). Again, an especially interesting discovery was made just at the close of the season's work when there was recovered a fine adult jaw fragment with three molar teeth *in situ*. (Locus A jaw, *vide infra*.)

During the field seasons of 1927 and 1928, some 6000 cubic metres of the *Sinanthropus* cave deposit had been excavated, more than 1000 boxes of fossil material had been transported to Peking for preparation, and above the level of the quarry terrace the deposit had been exposed over a vertical face some 18 metres in height by 28 in width (BOHLIN, 1927; LI, 1927; TEILHARD and YOUNG, 1930). In spite of this extensive working it was evident at the end of the first two years' investigation that a much longer period would yet be required before complete excavation of the deposit could be hoped for. Further, it became obvious that correlated field work elsewhere in China and in the neighbouring regions would be necessary before many of the geological, palæontological, and physiographic problems raised at Choukoutien could be answered.

Excavations and Field Work, 1929–32.

In order to meet this situation the Cenozoic Research Laboratory was organized as a special department of the Geological Survey of China, both to carry on field work at Choukoutien and to investigate general Cenozoic geology and palæontology throughout China. Funds in support of such investigation over a period of years were generously granted by the Rockefeller Foundation through the Department of Anatomy of the Peking Union Medical College, the head of the latter department being relieved of his academic duties to undertake the Honorary Directorship of the newly reorganized research.

The Cenozoic Research Laboratory functions as an integral part of the Geological Survey of China, whose director, Dr. W. H. Wong, is its official chief, and title to all material recovered during the investigation rests wholly with the Geological Survey itself. Dr. V. K. Ting kindly consented to act as Honorary Director of Cenozoic Research in China, and the professional staff of the Laboratory now includes Pere Teilhard de Chardin, Dr. C. C. Young, Mr. W. C. Pei, and Mr. M. N. Pien, while in addition, from time to time the services and advice of scientific collaborators, both from other departments of the Survey and from other institutions, are sought.

Excavations were resumed at Choukoutien by Mr. W. C. Pei in April, 1929. In view of the difficult approach to the vertical face of the main deposit, which in places was but poorly consolidated, Mr. Pei concentrated work on that part of Locality 1 known as the Lower Fissure, fig. 29. In the latter region, working downwards from the level of the quarry terrace, he extended the excavations to a depth of some 10 metres by quarrying out the limestone along the west wall of the fissure. During this excavation new *Sinanthropus* levels were encountered (Locus C and D) from which at the time several loose teeth were recovered, the season's work being brought to a dramatic close by Mr. Pei's discovery of the beautifully preserved adolescent *Sinanthropus* Locus E skull (Pei, 1930).

Negotiations for acquisition of title to the Choukoutien *Sinanthropus* site, which had been in progress for some time, were successfully concluded by the Geological Survey of China towards the end of May, 1930. Preservation of this classic site for scientific study having thus been rendered secure, Mr. Pei resumed his investigations of the Lower Fissure in June of that year, and at the same time began a very extensive series of quarries above and to the south of the Main Deposit in an effort to locate the southern boundary of the latter.

In the summer, during preparation of the material secured in 1929 from the *Sinanthropus* Locus D, a number of skull fragments were recovered from which it was possible to restore in large part the calvaria of an adult *Sinanthropus* (Locus D skull). Further work in the " Lower Cave " region of the Lower Fissure led to the discovery by Mr. Pei in the late autumn of a juvenile *Sinanthropus* jaw fragment in which almost the whole right posterior half was preserved (Locus F jaw).

In October, Professor G. ELLIOT SMITH's brief visit to Peking as guest of the Cenozoic Research Laboratory did much to promote the interests of our work, his sympathetic criticism and advice at that early stage of our investigation being especially helpful.

In April, 1931, before resuming excavation work, a careful re-study of the whole of the Choukoutien Locality 1 was made. Though the Lower Fissure had been explored to a depth of over 20 metres below the level of the quarry terrace, the bottom of the Main Deposit had not been reached. The mechanical difficulties to be overcome in transporting excavated material to the surface from the bottom of the Lower Fissure excavation were great. It was therefore decided to discontinue work there and to attempt to reach a similar level by excavating the breccia of the floor of Kotzetang cave. In laying out the preliminary survey of this work, a special study was made of the eastern end of the 1928 cutting. Access to this part of the deposit was difficult and could be had only through a narrow opening which in 1928 had been broken into the uppermost western part of the Kotzetang. Here there was now discovered a few undoubted, though indeed most crudely chipped, artifacts of vein quartz embedded in the hard breccia (Quartz Horizon 1, 51 ; fig. 30). This horizon was also characterized by the presence of much black pigment, the latter in places being of the consistency of wet powder. Chemical examination of this powder subsequently demonstrated that the black coloration was in fact almost entirely due to its high content of free carbon, such an accumulation of charcoal furnishing definite proof of the local action of fire (BLACK, 1931).

Quarrying operations in the hard breccia of the floor of Kotzetang cave, beginning at a level approximately 5 metres below that of Quartz Horizon 1, were begun by Mr. PEI, assisted by Mr. PIEN, towards the end of April. This work was pushed on vigorously, and before the end of June the now classic stratum known as "Quartz Horizon 2," or "Cultural Zone C," was encountered. Here thousands of crude stone artifacts were found *in situ* in actual association with *Sinanthropus* remains (Jaws G1 and G2 together with clavicle and skull fragments) in the fire-blackened strata of that horizon (PEI, 1931).

While Mr. PEI's preliminary description of these artifacts was in the press, Professor HENRI BREUIL arrived in Peking as guest of the Cenozoic Research Laboratory. By this fortunate circumstance he was enabled to study at first hand, both in the laboratory and in the field, the evidences upon which Mr. PEI had based his conclusions. Professor BREUIL's careful study fully confirmed Mr. PEI's observations. In addition, he very kindly added to these the interesting results of his own survey of the material, and by his keen insight and enthusiasm contributed greatly to the progress of our research (BREUIL, 1931).

Field work was resumed at Choukoutien in April, 1932, under the direction of Mr. PEI, assisted by Mr. PIEN. Excavations in the trench cut in the floor of Kotzetang were not resumed for a number of reasons. Chief among the latter was the conviction, now amounting almost to a certainty, that the original cave inhabited by *Sinanthropus* must have opened towards the east, not towards the north as heretofore had been supposed. If so, the remains of the ancient cave entrance must lie buried beneath the breccia and talus of lime waste accumulated on the eastern slope of the present hill. Further, it was necessary to carry out a very careful large-scale topographical survey and levelling of the Locality, on which could subsequently be plotted with accuracy the records of future excavations. This topographical work was undertaken by Messrs. J. T. FANG and S. C. WANG, and at the same time Mr. PEI conducted a detailed geological study of the site (BLACK and others, 1933, Map VI). Meanwhile, work commenced on the eastern hill slope, where the actual southern limits of the deposit surface were at last definitely defined. By the close of the 1932 field season a considerable area of the eastern part of the deposit had been excavated layer by layer from the top in the orderly fashion of an archæological excavation, accurate map and photographic records being made of every stage of its progress (see fig. 29).

An apparently mature *Sinanthropus* jaw specimen, together with a number of tooth fragments, were recovered from the Locus B area early last summer, but as this material is still incompletely prepared no description of it has yet been published. In addition to this skeletal material a large number of crude stone artifacts from the upper levels of the deposit were discovered *in situ* during the 1932 excavation (BLACK and others, 1933).

Future excavation of Locality 1 will be extended from the 1932 eastern surface working. Eventually it will thus be possible to investigate the entire extent of the deposit, layer by layer from the top, by a series of block excavations. It is planned, however, to leave *in situ* and undisturbed considerable masses of the original deposit, in order to preserve for future study a permanent record of its present general configuration, lithology, and stratigraphy.

Occurrence of Sinanthropus *Material within the Deposit.*

For convenience in recording, each place from which *Sinanthropus* fossil material has been recovered within Locality 1 has arbitrarily been designated a "*Sinanthropus* Locus." The first such place within the deposit thus became known as "*Sinanthropus* Locus A," and regardless of their stratigraphic sequence, each subsequent discovery site has received in turn its locus designation in alphabetical order. Up to the end of the field season of 1932 seven such loci have been recognized as follows :—

Locus A.—The original worn upper M3 recovered by ZDANSKY came from a level now known as Layer 5 (*i.e.*, at the base of Cultural sub-zone A*c*, fig. 30). It was from this level that the lower M1 was obtained by BOHLIN in 1927, and from which subsequently in 1928 the fragment of the right side of an adult lower jaw was obtained. This region of Layer 5 above the Lower Fissure has accordingly been distinguished from the outset as *Sinanthropus* Locus A.

Locus B.—In the vicinity of the eastern end of what is now known as Layer 4 (*i.e.*, Cultural sub-zone A*a*, fig. 30) a small pocket rich in *Sinanthropus* remains was discovered in 1928. From the material derived from this place in the latter year there have been recovered numerous isolated teeth both immature and adult, the greater part of the right side of a juvenile jaw, an *os lunatum* wrist bone and many skull fragments as yet incompletely prepared. Being second in the series this place was accordingly designated *Sinanthropus* Locus B, and from it in 1932 yet another *Sinanthropus* jaw fragment was discovered as noted above.

Locus C.—In June, 1929, when the upper levels of Layer 8, fig. 30, of the Lower Fissure were being excavated, PEI recovered *in situ* an adult *Sinanthropus* lower premolar tooth, and subsequently within a small radius of the same region five additional lower teeth were recovered (1 canine, 2 molars, 1 premolar, and 1 incisor). This region thus became known as *Sinanthropus* Locus C.

Locus D.—In September, 1929, when working Layer 9 of the Lower Fissure, a worn, adult, upper canine tooth of *Sinanthropus* was discovered *in situ* by PEI. From the same place there was subsequently recovered *in situ* the crown of a worn upper first molar, and other similarly worn teeth as follows : Upper canine, lower premolar, lower incisor ; while a worn upper central incisor was recovered when the loose material of the site was sieved. From the material derived from this place and brought to Peking for preparation, a worn lower molar tooth was recovered in the laboratory in March, 1930, while in the latter part of June skull fragments representing the greater part of an adult *Sinanthropus* calvaria were similarly found. The place from which all these specimens were derived was designated *Sinanthropus* Locus D.

Locus E.—On December 2, 1929, PEI recovered within a sheltered recess of the eastern lower cave of the Lower Fissure a beautifully preserved cranial portion of an adolescent *Sinanthropus* skull, the site of this discovery being designated *Sinanthropus* Locus E.

Locus F.—During further excavation of the eastern lower cave of the Lower Fissure in the following autumn, a *Sinanthropus* jaw fragment comprising the greater part of the posterior half of the right side of a juvenile specimen was recovered in a south-eastern extension of the cave. The site of this discovery thus became known as *Sinanthropus* Locus F.

Locus G.—In July, 1931, while excavating Quartz Horizon 2 (PEI, 1931 *c*) in the Kotzetang (Cultural Zone C, fig. 30), PEI discovered three fragments of an adult *Sinanthropus* skull, together with two adult jaw fragments (G1, including the complete left lower dental arcade ; G2, including the whole right posterior jaw region). All these specimens occurred within an area less than one metre in diameter, associated with crude artifacts and embedded in a black charcoal-laden stratum. Subsequently, from the same horizon but somewhat further removed, there was recovered the greater part of the shaft of a stoutly-built left clavicle. The region from which all these specimens have been recovered was designated *Sinanthropus* Locus G.

It thus becomes evident that *Sinanthropus* remains occur irregularly throughout the whole deposit of Locality 1 and in special association with the cultural ashy layers.* Up the present no *Sinanthropus* skeletal material has unquestionably been recovered from any of the fossiliferous deposits of Choukoutien except Locality 1 (BLACK and others, 1933). The one possible exception to this is a fragment of a fossilized hominid radius lately recovered in the laboratory among material said to have been derived in 1927 from Locality 3. The possible significance of this is discussed below where a brief description of the specimen will be found.

In view of the foregoing résumé, the various specimens now to be described may be referred to simply by their Locus designations, and further consideration of the latter deferred.

GENERAL MORPHOLOGY OF *Sinanthropus*.

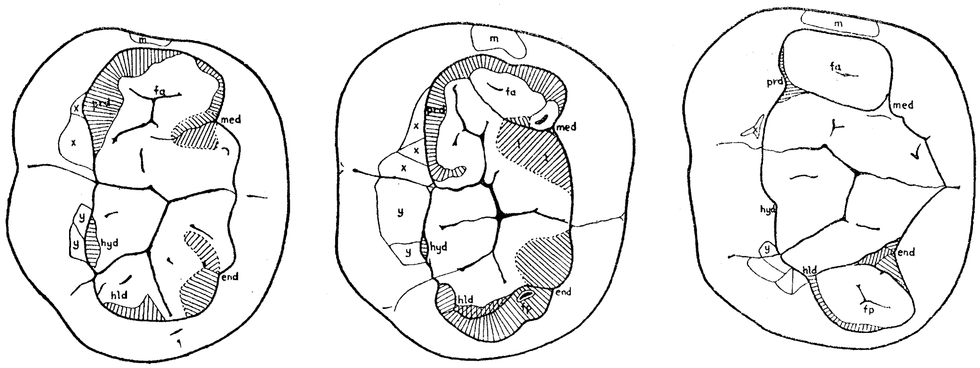
Dentition.

No systematic study has yet been published of the dental morphology of *Sinanthropus* other than that of the lower molar tooth from Locus A, described in 1927 (BLACK, 1927 *b*). Since that date a sufficient number of additional specimens has been recovered from the various *Sinanthropus* Loci (A, B, C, D, F, and G), amply to confirm the general conclusions then drawn as to the lower molar morphology. In addition to the further lower molar material thus acquired, examples representing one or more of each of the other tooth types of the adult *Sinanthropus* dentition have similarly been recovered. Thus it now becomes possible to present, in the following brief descriptions, a reasonably complete picture of the general morphology of the teeth of both lower and upper arcades.

Lower Dental Arcade.—The crowns of the lower molar teeth in *Sinanthropus* display a characteristic tendency to be somewhat trapezoid in outline, the major transverse diameter being across the mesial moiety of the tooth (cf. figs. 4, 6, 13, and 14). The crowns are low in comparison with the corpus height, the index of this ratio being about 50 as compared with that of about 80 for modern man and anthropoids. This characteristic is to be correlated with the roominess of their crown pulp chamber, fig. 5, which at all stages of growth is much greater than in the corresponding stages of any modern anthropoids or of recent man. The roots of M2 and M3 may reach or project into the inferior dental canal (Locus G1 and G2 jaws; BLACK, 1933 *c*, Plate VII, figs. 2 and 3), or fall some distance short of the latter (Locus A jaw; Black, 1929, *a*, Plate VII, fig. 1; Plate VI, fig. 1). The crown pattern is characteristically of a well-marked *Dryopithecus type*, fig. 4. The shape of the occlusal trough and the character of dental wear are both like that of modern man, the latter character attesting to the essential similarity of jaw movements in the two forms, fig. 4. The first molar tends to be the largest of the series, though all three molars are functional. The last molar may be much reduced

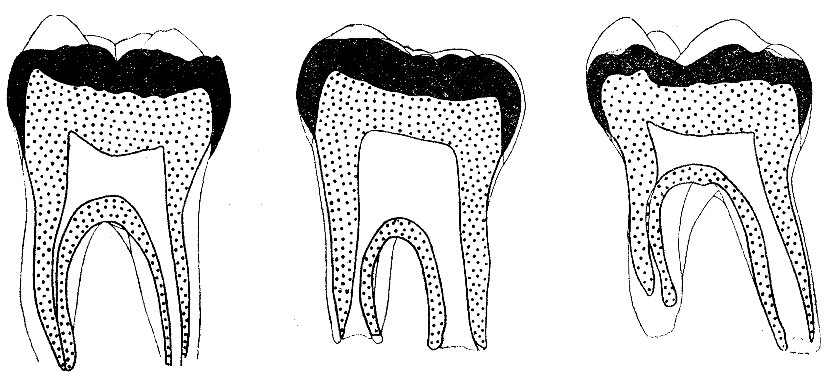
* Even for Loci C, D, and E it is probable that such an association will become evident as soon as it becomes possible to investigate the connections between the levels of the main deposit and the ramifications of the lower caves, for stone artifacts have certainly been found in the lower fissure (BLACK and others, 1933).

in size as compared with the second and first, or it may approximately equal the former in development, fig. 6. The deciduous lower molars are essentially similar to the



(*a*) (*b*) (*c*)

FIG. 4.—Drawings for comparison of details of crown morphology and wear in left lower first permanent molar teeth (occlusal views), (*a*) recent N. China child (♂ 44) aged about 10 years; (*b*) Locus A *Sinanthropus* juvenile specimen, and (*c*) juvenile Chimpanzee (Cat. No. 18) of same ontogenetic stage of development as other specimens. Abbreviations: *end*, entoconid; *fa*, fovea anterior; *fp*, fovea posterior; *hld*, hypoconulid; *hyd*, hypoconid; *m*, second deciduous molar contact facet; *med*, metaconid; *prd*, protoconid; *x*, *x* and *y*, *y*, labial crown wear facets. All wear facets within the margin of the occlusal trough, shaded with fine oblique lines, their outlines being dotted except where they make marginal contacts; areas of tabular wear on the margin itself, shaded with fine radially arranged lines; wear facets upon the labial surfaces of the hypoconulid, hypoconid, and protoconid, indicated in outline. All three drawings at same magnification (circa × 3).



(*a*) (*b*) (*c*)

FIG. 5.—Enlarged skiagram tracings of left lower first permanent molar teeth, (*a*) recent N. China child (♂ 44) aged about 10 years, (*b*) Locus A *Sinanthropus* juvenile specimen, and (*c*) juvenile Chimpanzee (Cat. No. 18) of same ontogenetic stage of development as other specimens. Orientation: lingual surface towards paper, mesial surface towards left of observer; all three tracings at same magnification (circa × 2).

permanent teeth in respect to the proportions of crown and corpus height, but apart from this character would seem to be typically modern in their morphology, fig. 13.

As in the original type lower molar of *Sinanthropus*, the thickness of the crown enamel in other unworn specimens is distinctly greater than that in modern man and anthropoids, fig. 5.

The lower premolars are somewhat variable in their development so far as the length of the root is concerned. Either, apparently, may exceed the other in root length, but the first may be double (*e.g.*, G1 ; BLACK, 1933, *c*, Plate VII, fig. 2), as occasionally happens in modern man. In crown dimensions they are also variable, but tend to resemble the lower molars in their low crown height.

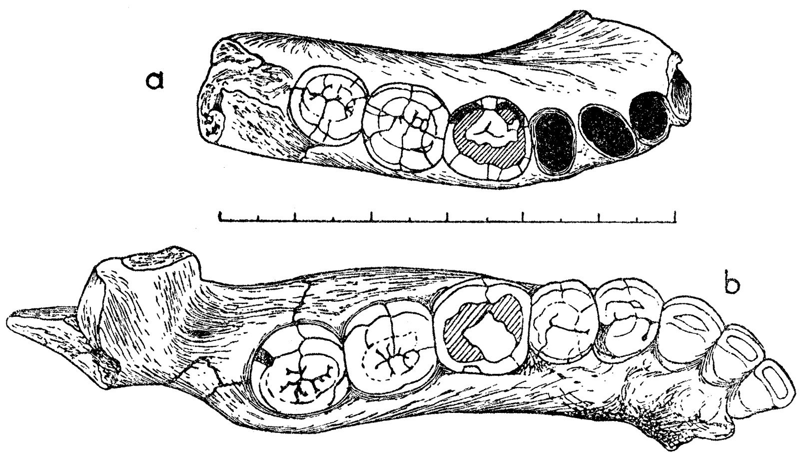


FIG. 6.—Dioptrograph drawings of occlusal views, (*a*) of Locus A *Sinanthropus* jaw fragment and (*b*) of Locus G1 *Sinanthropus* jaw fragment. Natural size.

The lower canines are well developed and long rooted but, though massive, their crowns are low, as in the premolars, and do not project above the general level of the dental arcade. There is no tendency whatever toward the development of a diastema, fig. 14.

The lower incisors are stout well-formed teeth, the lateral, as in modern man, being larger than the medial pair. They differ markedly from modern man in the extraordinary length of their roots, which extend far down into the symphysis region to a degree greater than that obtaining in modern anthropoids (BLACK, 1929, *a*, Plate V, fig. 1 ; BLACK, 1932, *c*, Plate VI, fig. 5). The bite is characteristically edge to edge in both juvenile and adult jaws.

Upper Dental Arcade.—Curiously enough, the upper dentition of *Sinanthropus* is as yet much less extensively illustrated amongst our material than the lower. Nevertheless, a sufficient number has been recovered, so that each tooth type is represented by one or more specimens.

Three well-preserved upper last molars are at present known, and in each there is displayed the characteristic tendency to fusion of the three roots, which was so evident in the original molar tooth discovered by ZDANSKY (1927, *a*, 1928). Like the latter, also, these molars display all the evidences of reduction in size, and masking of crown pattern, so prevalent in modern wisdom teeth. These teeth are low-crowned, show but slight evidence of a cervix, have extensive crown pulp cavities, and resemble the lower molars in the thickness of their crown enamel.

Three almost complete and but little worn specimens, together with one represented by the greater part of its crown only, and others more fragmentary, have so far been recovered, and serve to illustrate the morphology of upper first and second molars of *Sinanthropus*. Definite distinction between isolated first and second upper molars of *Sinanthropus* is not possible at present. As in the lower teeth, there is a tendency for the mesial to exceed the distal moiety in crown diameter. The crown is low, the corpus height resembles that of the lower molars, and like the latter also the crown pulp cavity is more roomy than in modern man or anthropoids. There is a considerable variation in absolute crown size between the three well-preserved specimens, but all are similar in proportion. The cervical region is very slightly marked and the lingual root is stout and conical. In one specimen the latter is more divergent from the buccal roots than in the others, in which it passes upwards almost at right angles to the crown plane. In one of the latter specimens the distal buccal root diverges from the mesial, while in the other all three root apices are but little separated from one another.

The upper premolars are represented by several specimens. The crown is low and massive and the root conical. Except to note the variability of their total length from crown to apex, they require no further description here.

The upper canines are represented by three perfect specimens and they are extraordinarily massive and long rooted. Their crowns, like the premolars, are low and each of the three show the characteristic wear of an edge-to-edge bite.

Two but little worn lateral upper incisors, with incompletely formed root apices, display a crown morphology quite typical for this region in various races of modern man (HRDLIČKA, 1920). Three mammelons characterize the occlusal edge, a small central one, and two almost symmetrical lateral, larger ones. The crista dentalis is rounded and well formed along the mesial and distal margins of the crown. From both sides, however, the cristæ slope gently towards a shallow medial trough, whose upper end terminates at the central mammelon. In these specimens, therefore, the lingual dental fossa may best be described as semi-shovel-shaped (HRDLIČKA, 1921). There is no fovea dentalis present. Several other lateral incisors with worn occlusal edges and completely formed roots have been found, the roots in all being longer than in modern man.

Only one specimen of a fully formed and but moderately worn left upper median incisor has so far been recovered. This tooth has a large well-formed crown, the enamel of the occlusal edge being worn just to the point where a well-marked line of dentine becomes exposed. This wear is characteristic of an edge-to-edge bite. The lingual fossa is typically shovel-shaped (HRDLIČKA, 1920), with highly developed cristæ and massive tuberculum dentale. The root of this tooth from the gingival lingual margin of the crown enamel to the apex is 17 mm. in length. The upper central incisors among the modern inhabitants of North China are, as a rule, unusually well developed; yet among more than 50 such teeth available for comparison only one specimen was found to equal in root length the *Sinanthropus* incisor, and of the remainder only 4 attained to within 3 mm. of such length. Nevertheless, on account of the breadth and massive structure of its crown, the *Sinanthropus* specimen at first view gives the impression of being quite short and conical.

Significance of Type.—No detailed discussion can be attempted under this heading, but, in view of their important phylogenetic bearing, three groups of morphological characters require further consideration here.

In the lower molar teeth of *Sinanthropus* there is a very evident tendency toward a trapezoid crown outline as the result of the labio-lingual diameter of the mesial, exceeding that of the distal crown moiety. This tendency is most strikingly evident in M1, though it may be observed also in each of the other teeth of the lower molar series. The prevalence of this character having been established in the numerous *Sinanthropus* lower molar specimens now available, its probable significance will once more be emphasized.

Attention has been drawn to the relative proportions of corpus to crown height in both the upper and lower molars of *Sinanthropus*, and correlation of this character with the large size of the crown pulp cavity has been noted. A further interpretation of these significant characters is offered below.

In view of the undoubted similarities in the general morphology of their calvaria, between *Sinanthropus* and *Pithecanthropus*, a general comparison has been made between the dentition of these two forms so far as this is at present possible.

Lower Molar Crown Morphology.—The difference between mesial and distal lower molar crown diameters in *Sinanthropus* is due to a disproportionate relative development of the entoconid and metaconid, fig. 4. It may be said that the entoconid region is relatively slightly developed or, conversely, that metaconid development is relatively great; but certainly the difference between these crown diameters is not due to an evenly distributed under-development of the whole distal moiety.

The detailed studies of GREGORY and HELLMAN (1926) have undoubtedly demonstrated that the loss of the *Dryopithecus pattern* and the development of a characteristic *plus-pattern* in the lower molar crowns in modern man is associated with a forward movement and increased relative size of the entoconid, the latter element in primitive forms being characteristically smaller than the metaconid, and distal in its position. Thus in their occlusal pattern and entoconid development the lower molars in *Sinanthropus* must be considered as of a generalized and progressive type, that is, one whose slight modification in a given direction may readily produce a condition dominant in modern hominids.

Molar Pulp Cavity.—Both in the lower and in the upper molar teeth of *Sinanthropus* the crowns are low in comparison to the body height, a condition to be correlated with the roominess of their pulp cavities, fig. 5. Throughout their developmental history after acquisition of definite roots, the crown pulp cavities of the molar teeth in *Sinanthropus* are strikingly larger than those of modern man or anthropoids of corresponding ontogenetic age. Particular attention was drawn to this feature in the type molar first described (BLACK, 1927, *b*), and at that time it was thought to indicate a moderate taurodontism.

However, KEITH'S (1913) original term taurodontism was devised to describe Neanderthal teeth, and was defined as the condition resulting from an extension of the pulp cavity below the supporting alveolar border, to constitute a true encroachment upon what is normally, in modern man, the root region. In contrast to taurodontism, KEITH employed the term cynodontism to define the normal relation of the molar pulp cavities to the supporting alveolus in modern man and anthropoids. Consequently the use of the term "slight taurodontism" to describe the lower molar type tooth of *Sinanthropus* carries with it the implication that the large pulp cavity in that form is extended at the expense of the root area, below the level of the supporting alveolus. This we now know was not so in *Sinanthropus* (BLACK, 1929, *a*, Plate VI, fig. 1; BLACK, 1933, *c*, Plate VII, figs. 1, 2, and 3), in which the roomy pulp cavity lay almost wholly above the supporting alveolar border.

In comparison with the molar pulp cavities of modern man and anthropoids, the definitely larger and roomier pulp cavities in the molars of *Sinanthropus* is an observation now supported both by a large series of examinations of isolated teeth, and also by skiagrams of three jaw specimens in which the latter have been preserved *in situ*. In the jaw skiagrams, the true relations of these large pulp chambers to the root region and the supporting alveolar margin is clearly evident. Since it is impossible correctly to define this condition as one of taurodontism in *Sinanthropus*, and since the latter form displays the character in question so unequivocably, a new descriptive term is wanted to define clearly a condition which would seem to be of phylogenetic importance.

It has been proposed that this roominess of the molar pulp cavity (occurring wholly in the *corpus dentis* without regard to the relation of the latter to the alveolar margin) which is so evident in *Sinanthropus*, be termed *megaphanic** in contrast to a *microphanic* condition observed in modern anthropoids and man (BLACK and others, 1933). New terms are suggested because there is evident need for some special name to describe a condition, the probable significance of which heretofore has not been clearly recognized. These terms have been used in this laboratory in the above sense for some time, since no other unambiguous ones were known to us. Taurodontism could thus be defined as a specialized extension of an earlier megaphanic condition to become that characterizing Neanderthal man, while cynodontism would be a special microphanic condition characterizing modern anthropoids and man.

Regardless of what term be used to describe the condition, the fact remains that in this early and generalized hominid *Sinanthropus*, there is a roomy molar pulp cavity

* φαν phan = reveal.

which does not encroach upon the root zone but extends above the border of the supporting alveolus (megaphanic condition). However, in the later hominid representatives known to us, two very widely divergent conditions obtain (taurodontism in the Neanderthaler and cynodontism in modern man), neither of which could well be derived from the other.

It is therefore probable that a megaphanic condition characterized the molar teeth of the stem form from which both Neanderthal and modern man were derived. If this be so the subsequent development within the hominid family of two such opposite and widely divergent tooth types may readily be understood. One of these types, the extreme taurodontism of the Neanderthal, would then be understood as the product of advanced specialization; the other, being the condition characterizing *H. sapiens*, as resulting from degenerative change. The latter conviction is strengthened when it is recalled that most of the distinctive peculiarities of the teeth of modern man are almost certainly degenerative in origin, a conclusion clearly demonstrated by GREGORY and HELLMAN (1926).

On the Teeth of Sinanthropus *and* Pithecanthropus.—In its general morphology, the first lower premolar tooth of *Pithecanthropus* appears to resemble in all essentials the corresponding tooth of *Sinanthropus*. Most of the specimens of the latter available for comparison are, indeed, of somewhat larger size; but apart from this, the bifid root condition of the first lower premolar in the *Sinanthropus* Locus G1 jaw, exactly reproduces the condition obtaining in the isolated *Pithecanthropus* specimen (BLACK, 1933, *c*, Plate VII, fig. 2).

Unfortunately as yet no skiagrams of the two upper molar teeth of *Pithecanthropus* are available. However, from a study of the excellent casts of these made by BARLOW, and from DUBOIS' (1924) beautiful figures it is very evident from their external proportions alone that the pulp cavities in neither tooth can well be of the roomy megaphanic type, for in each the low crowns are set upon a corpus of relatively diminutive height.

The upper molars of *Pithecanthropus* are of an extraordinarily specialized type. Their extreme cervical (collum) development is comparable only with that obtaining in some modern anthropoids and in the deciduous molars of modern man. In this respect, therefore, they present a sharp contrast to those of *Sinanthropus*. Except for its low height, the megadont molar crown morphology of *Pithecanthropus* is also utterly unlike either that of *Sinanthropus* or of the more modern hominids.

The massive lingual molar roots in both the *Pithecanthropus* specimens diverge mediad at a wide angle from the crown plane. They are equally well developed in both specimens (M2 and M3). They are broad and flattened labio-lingually, beginning to taper sharply at a short distance from their apices. The labial roots are fused in both specimens and they, like the lingual roots, diverge laterad at an angle to the crown plane, this angle being the more pronounced in the M3 specimen.

The upper molar teeth in *Pithecanthropus* thus present in these highly specialized characters a very wide contrast to those of *Sinanthropus*; a contrast quite as great, though of a different kind, as that to be observed between the specialized molars of Neanderthal and modern man. By no possible effort of the imagination could one derive a generalized upper molar tooth such as that of *Sinanthropus* from the highly specialized *Pithecanthropus* type.

Mandibulæ.

Up to the beginning of the field season of 1932, six *Sinanthropus* jaw fragments* had been recovered from Locality 1. Illustrated preliminary reports on the first two jaw fragments recovered (Locus A and B jaws) were published in 1929 and 1930 (BLACK, 1929, *a*, *b*, *c*); and a further brief preliminary report on the fully prepared Locus B jaw and on four additional specimens (Locus C, F, G1, and G2 jaws) appeared in 1931 (BLACK, 1931, *a*).† During the further excavations of the Locus B region last season, a second series of jaw fragments (Locus B2 jaw) were discovered. Owing to the hardness of the matrix and the shattered condition of the contained specimens, preparation of the latter cannot be completed for some time. It may be noted, however, that the fragments would seem to include at least a considerable part of the symphysis region of a mature individual.

Locus A Jaw Fragment.—This fragment was recovered from the main deposit towards the close of the 1928 excavations, figs. 6 and 7. It is highly mineralized and deeply pigmented, as are all fossils derived from Layers 4 and 5. This specimen comprises the greater part of the right horizontal ramus of an adult lower jaw, with the three molar teeth *in situ* and the premolar, canine, and distal half of the lateral incisor sockets preserved. Some 13 mm. of the lower margin of the horizontal ramus is also preserved intact in the region below the first premolar socket. There is a very evident diminution in the size of the molar teeth from before backward. Four mental foramina occur, and a raised and roughened area for muscular attachment of the platysma-triangularis sheet is to be observed in front of the foraminal region along the inferior margin of the ramus.

Locus B Jaw Fragment.—This specimen was discovered during the excavations carried on in the summer of 1928, being found unexpectedly in a richly fossiliferous pocket at what was then considered to be the most eastern extension of the cave deposit, see fig. 30. The pocket lay immediately below a cemented stratum of lime waste derived from modern quarrying operations, and consisted of a very hard travertine

* Casts of each of these jaw fragments have been prepared, and copies made by Mr. F. O. BARLOW may be obtained from Messrs. R. F. Damon & Co., London, authorized agents of the National Geological Survey of China. Authorized copies of casts of many of the other *Sinanthropus* specimens here described may also be obtained from that firm.

† In 1932 preparation of the final report on this important material was commenced for publication in Palæontologia Sinica, Series D, and the seven plates to illustrate the report were printed by the end of that year. Completion of this work has been delayed, but its publication in 1933 is anticipated.

mass which, when broken into, displayed its rich fossil content. Subsequently it became evident that piercing of this travertine first began in the immediate neighbourhood of the jaw specimen, whose presence was only betrayed on the appearance of newly fractured and light coloured bone and tooth fragments. Large blocks of the travertine were then removed and transported to Peking for preparation, and a careful collection was made of all the associated small bone and tooth fragments. From this material it was possible subsequently to restore the greater part of the right side and entire symphysis region of a juvenile *Sinanthropus* lower jaw, the completed specimen being here illustrated in fig. 8.

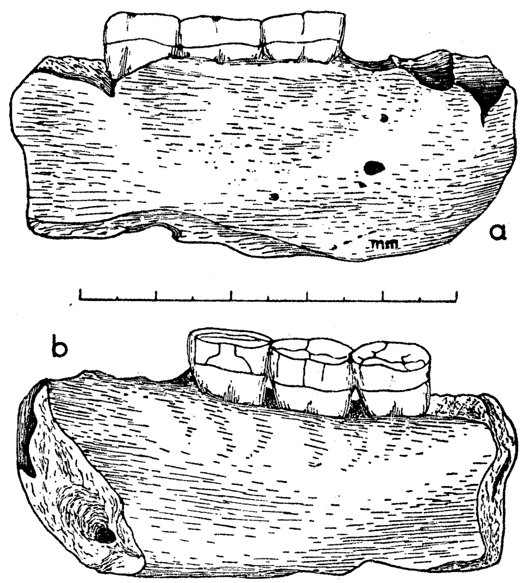


FIG. 7.—Dioptrograph drawings of the Locus A *Sinanthropus* jaw fragment: (*a*) labial view, (*b*) lingual view. Abbreviation: *mm*, roughened area for platysma-triangularis attachment. The four multiple mental foramina are indicated. Natural size.

In this specimen the first permanent molar is erupted and functional, the deciduous molars and both right and left deciduous canines were *in situ*, while the permanent incisors had attained nearly to complete development (BLACK, 1929, *a*, Plate V, fig. 1). The tooth germs of both permanent canines were present and are exposed on either side in the substance of the jaw ramus where the latter has been fractured. The tooth germs of both right permanent premolars are also preserved within the original specimen (BLACK, 1933, *c*, Plate VI, fig. 1), but are not now visible. The unerupted tooth germ of the second permanent molar is exposed by a break in the alveolar wall, and the site of lodgment of the uncalcified germ of M3 is filled with travertine. Evidence of the presence of at least two mental foramina is preserved. A complete picture of the symphysis morphology may be had from a study of this specimen and a short account of it has already been published (BLACK, 1929, *a*, fig. 1). A dioptrographic outline of this symphysis is illustrated here in fig. 13.

Locus C Jaw Fragment.—A considerable number of fossiliferous blocks of hard travertine removed in 1929 from *Sinanthropus* Locus C in Layer 8 of the Lower Fissure were later sent to Peking for preparation. In the summer of 1931, while the last of the material from this site was being prepared, a part of the crown of a molar tooth of *Sinanthropus* was observed, protruding from one of the fractured faces of a block. Subsequent development of the latter disclosed the presence within it of a fragment of an immature right lower jaw, comprising a considerable part of the angular region

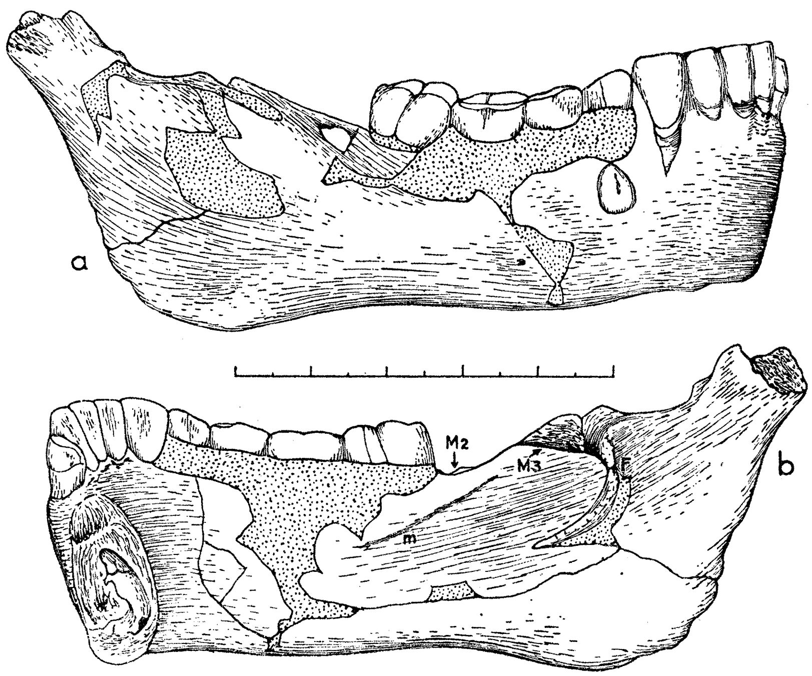


FIG. 8.—Dioptrograph drawings of (*a*) labial view, (*b*) lingual view of the restored right half of the juvenile *Sinanthropus* Locus B jaw. The restored portion of the horizontal ramus together with its broken surfaces and those of the ascending ramus behind the permanent molar are indicated by stippling. The unerupted permanent canines are both partially exposed. Abbreviations: *m*, mylohyoid line; *F*, foramen mandibulare; *M2*, exposed but unerupted second permanent molar; *M3*, travertine mass filling cavity for lodgment of M3 tooth germ. Natural size.

and the broken posterior alveolar margin. The latter supported *in situ* an unerupted third lower molar tooth below which was preserved the foramen mandibulare, fig. 9. Thus the fragment was evidently derived from an adolescent individual.

Locus F Jaw Fragment.—This specimen was discovered toward the close of the field season of 1930 in the Lower Cave region of the deposit. It comprises the greater part of the whole posterior region of a right jaw ramus of a juvenile individual, of approximately the same ontogenetic age as that from Locus B, fig. 10. The recovery of this specimen thus provided the precise information necessary to enable a complete dioptrographic reconstruction to be made of the juvenile *Sinanthropus* mandible.

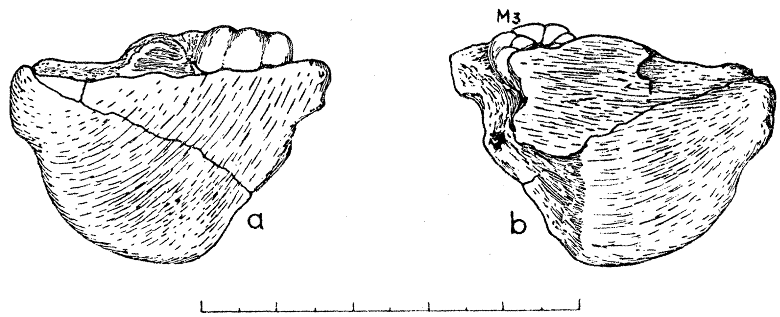


FIG. 9.—Dioptrograph drawings of (*a*), labial view and (*b*), lingual view of *Sinanthropus* Locus C adolescent jaw fragment. The extent of the unbroken margin of the angulas mandibulæ is indicated in outline and broken surfaces by shading. Abbreviations: *F*, foramen mandibulare; *M3*, exposed but unerupted third molar. Natural size.

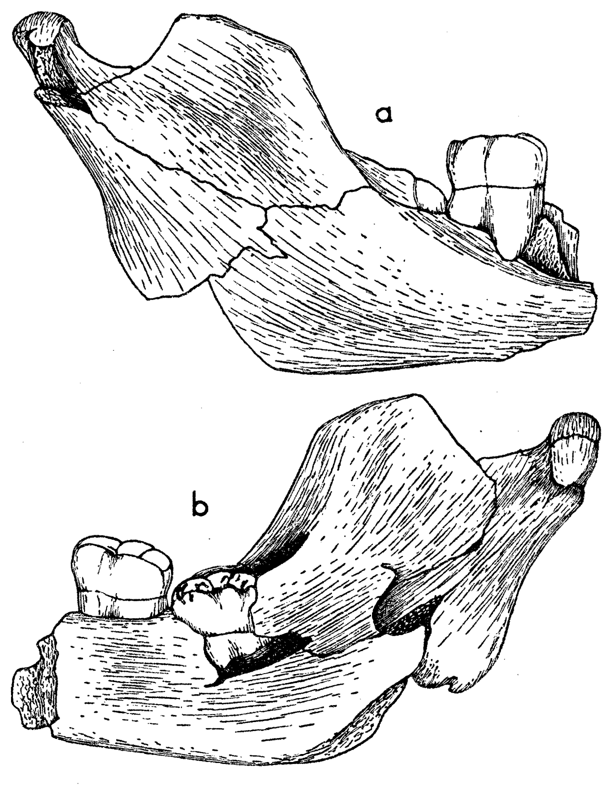


FIG. 10.—Dioptrograph drawings of (*a*), labial view and (*b*), lingual view of the juvenile *Sinanthropus* Locus F jaw fragment. The first permanent tooth was erupted and functional, the lateral alveolar margin being broken so as to expose partially its roots. The second permanent molar is unerupted but exposed by breakage of the alveolar margin, its partially formed roots also being exposed on the lingual surface of the fragment. Unbroken parts of the fragment are drawn in outline and fractured surfaces indicated by shading. Natural size.

*Locus G*1 *Jaw Fragment.*—This specimen, together with the next one to be described, was recovered from Quartz Horizon 2 of the Kotzetang area during the excavation of that region in the summer of 1931. Unlike previously discovered jaw fragments, this one is from the left side and comprises the greater part of the horizontal ramus of an adult jaw, supporting *in situ* the complete left lower dental arcade of a mature individual (see figs. 6, 11, and 14). Five mental foramina are present and the roughened

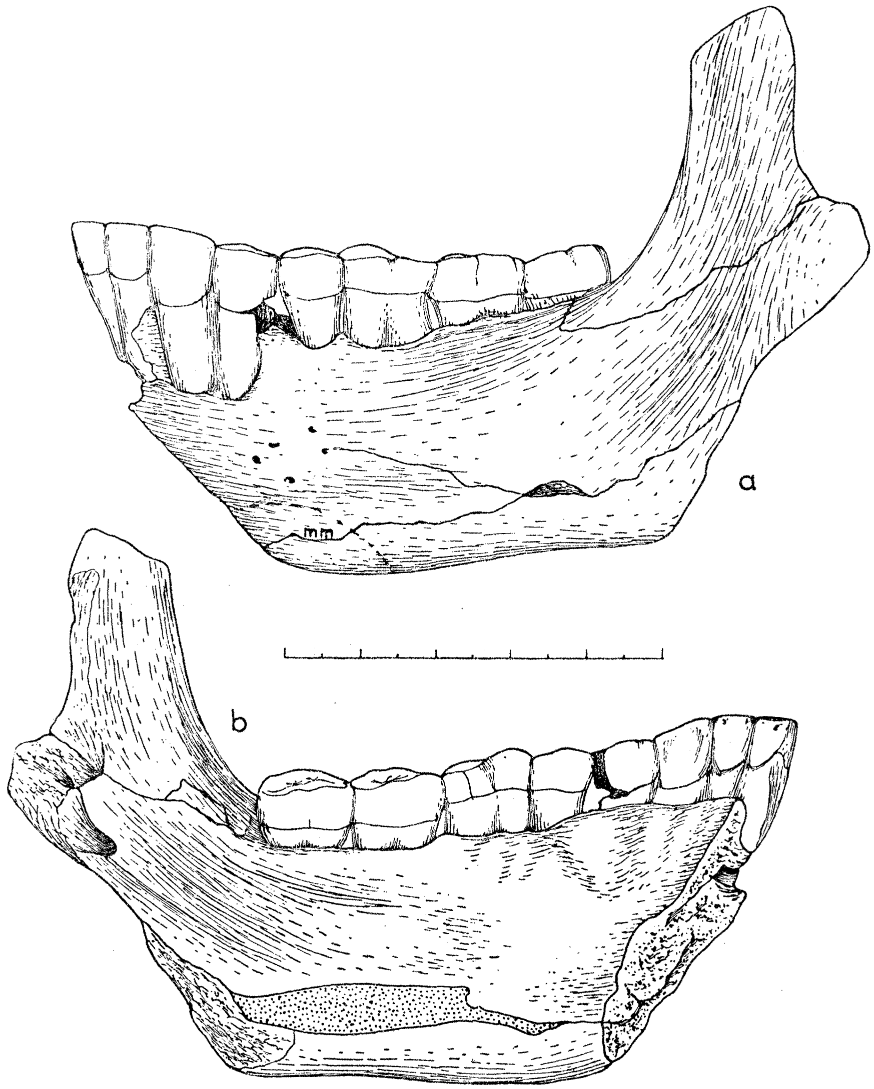


FIG. 11.—Dioptrograph drawings of (*a*), labial view and (*b*), lingual view of the adult *Sinanthropus* Locus G1 jaw fragment. The complete left permanent dentition is preserved in this specimen. In the drawing the five mental foramina are indicated. Abbreviations: *mm*, roughened area for platysma-triangularis attachment. Natural size.

area for platysma-triangularis muscular attachment which was so evident on the Locus A fragment, is represented here also by a roughened area below the mental region. In this specimen, however, unlike the Locus A jaw, the last molar tooth is not markedly reduced in size as compared with M2.

Locus G2 Jaw Fragment.—This specimen was found within 80 cm. of the G1 fragment and is from the right side of an adult jaw. The specimen includes a part of the horizontal ramus with M2 and M3 *in situ*, together with the complete angle and ascending ramus including intact both condylar and coronoid regions, figs. 12 and

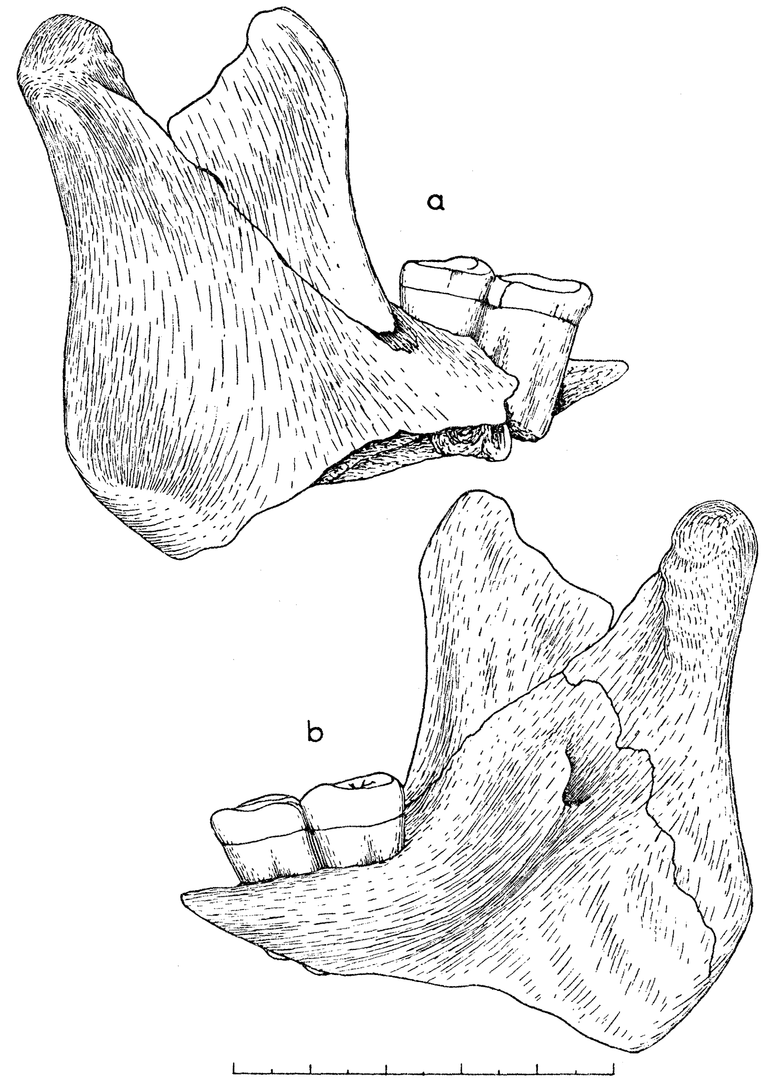


FIG. 12.—Dioptrograph drawings of (*a*), labial view and (*b*), lingual view of the adult *Sinanthropus* Locus G2 jaw fragment. The second and third molars in this specimen are preserved *in situ*. Unbroken parts of the fragment drawn in outline, broken surfaces being indicated by shading. Natural size.

14. The G1 and G2 fragments may possibly represent parts of a single jaw specimen, for in spite of the evident difference of molar wear in the two, their general dimensions in the region of overlap are closely comparable.

The condylar process is essentially hominid in form. The area for external pterygoid muscular insertion is unusually extensive and well marked ; on the outer surface of the condylar region the area of attachment of the tempero-mandibular ligament is similarly prominent.

The incisura mandibulæ is moderately shallow, and the coronoid process broad and massive to accommodate insertion of the extensively developed temporal muscle. The angulus mandibulæ is quite markedly everted, serving to increase the wide area available for insertion of the masseter muscle. The area for internal pterygoid muscular insertion is very extensive and markedly roughened, extending up to the mylohyoid sulcus. The latter is well marked and a prominent lingula overhangs the wide foramen mandibulare.

Dioptrographic Reconstructions.

From the foregoing brief descriptions it becomes evident that an accurate idea of the morphology of the whole juvenile *Sinanthropus* lower jaw may be had by a study of the three immature fragments so far recovered (Locus B, C, and F jaws), since in these specimens all parts of the right side are represented and in the Locus B specimen the complete symphysis region has been preserved.

In the adult *Sinanthropus* jaw, however, a small area of the latter region is not represented on any of the three specimens available for study (Locus A, G1, and G2 jaws). In dioptrographic reconstruction of the adult jaw, therefore, it has been necessary to model the restored symphysis region on the basis of its juvenile form, a circumstance which of course renders an exact restoration impossible in view of the probable marked changes which occurred during development of this region. Accordingly that part of the adult symphyseal region not actually represented on one or more of the jaw fragments has been indicated by interrupted lines, the remainder of the reconstruction representing conditions actually known to have obtained in adult *Sinanthropus* jaws.

The reconstructions illustrated here at reduced size were prepared for the final report on the *Sinanthropus* mandibulæ to be published shortly in Palæontologia Sinica, Series D. In view of the subsequent discovery of the Locus B2 jaw fragment, in which it would seem that a considerable portion of the adult symphysis is represented, it is hoped that dioptrographic reconstruction of the adult *Sinanthropus* jaw corrected as to symphysis detail may be included in the final report to be issued this autumn.

With regard to the technique employed in making these reconstructions, it may be well to stress the fact that they represent dioptrographic projections, not perspective drawings. The various fragments were oriented with regard to three sides of a glass cube, with the mean occlusal plane horizontal. Further adjustment of orientation with regard to the mid-sagittal plane was then made in comparison with both recent and fossil hominid material. Six dioptrographic normæ drawings were then made of each specimen so oriented. Subsequently these tracings were adjusted with regard to overlap and planes of orientation to permit the final drawings to be made, only two of the normæ views being here illustrated.

The Juvenile Sinanthropus *Jaw.*—Except for its symphysis morphology, the jaw in general is extraordinarily neanthropic in appearance, fig. 13. The obliquely set condyles and divergent limbs of the dental arcade are typically modern in their form. On the other hand, the even thickness of the horizontal ramus throughout the molar region is a quite archaic feature. It may be noted that the evidence on the latter point, together with that regarding the dental arcade, which has been preserved in the Locus B specimen, permits no other interpretation than that of the reconstruction. The Locus B

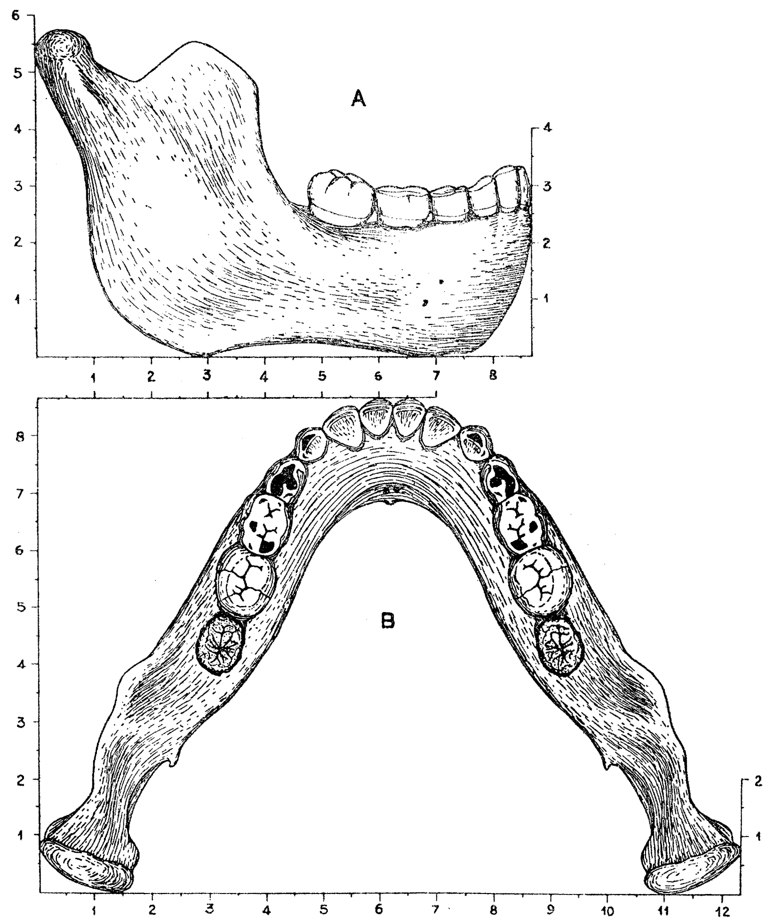


FIG. 13.—Dioptrographic reconstructions of the juvenile *Sinanthropus* jaw; A, labial view, B, occlusa view. Scale in centimetres × 3/4.

and Locus F specimens were combined at a level of the mesial margin of M1, in construction of the posterior half of fig. 42, so there is therefore some margin for error to be allowed when reading off such measurements as bicondylar breadth and projected mandibular length from the reconstruction. Nevertheless this error cannot at most be a very great one, and in addition to the general morphology illustrated, the drawings may be taken as giving a fairly accurate idea of the size and proportions of this interesting type.

The Adult Sinanthropus *Jaw.*—In the construction of fig. 14, mirror images respectively of the diagraphs of the Locus G1 and G2 fragments, overlapping upon M2, were combined with one another to form the right and left halves of the reconstruction.

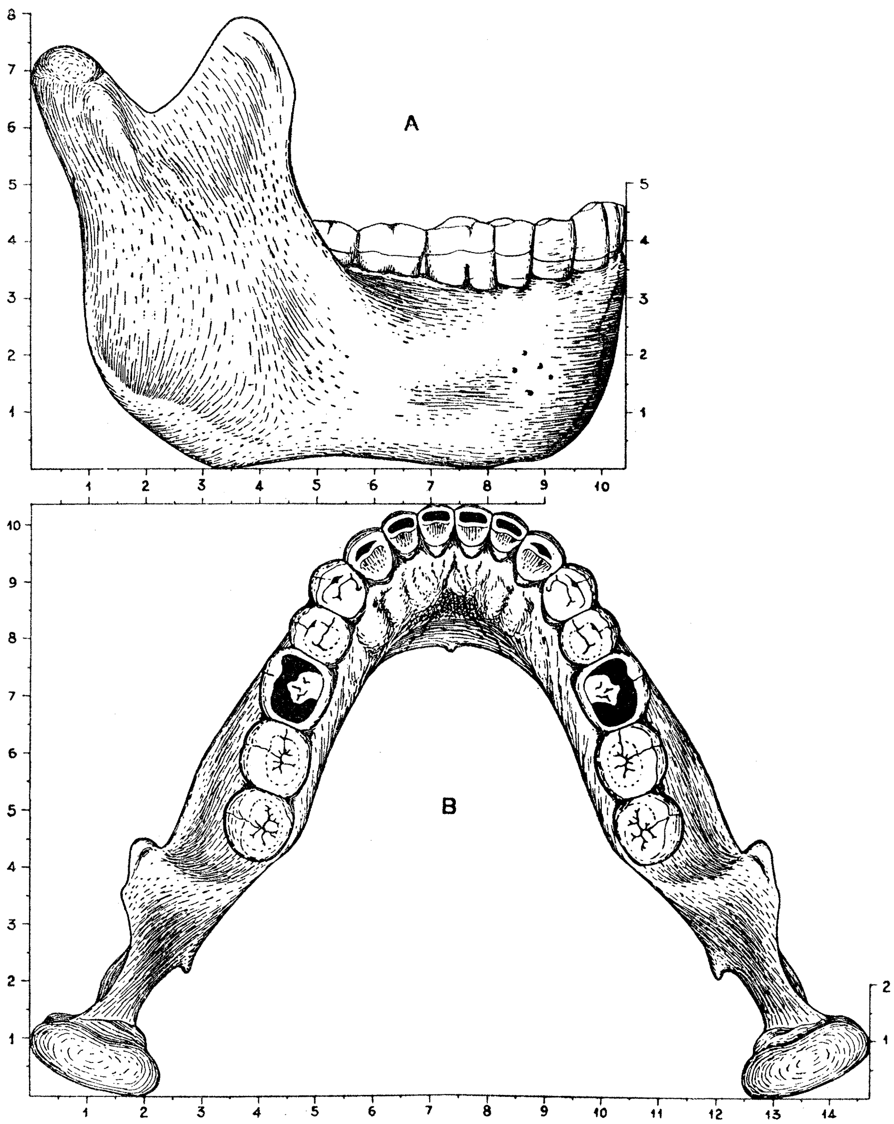


FIG. 14.—Dioptrographic reconstructions of the adult *Sinanthropus* jaw; A, labial; B, occlusal view. That part of the symphysis region which is conjectural (as not actually represented on any of the original specimens) has been indicated by interrupted lines in each of these reconstructions. Scale in centimetres × 3/4.

After experimental manipulation these halves were then combined. It is of course obvious that the preserved mesial contact surface of the first left lower incisor provided only one fixed landmark for the resulting reconstruction. Of necessity, therefore, a greater range of error than for fig. 13 must be allowed for in the adult reconstruction, when reading therefrom projected measurements such as mandibular length and bicondylar breadth. In its general features, however, the reconstruction presented accurately reflects our present knowledge of the morphology of the adult *Sinanthropus* mandible.

In the adult as in the juvenile stage, the general aspect of the *Sinanthropus* jaw would seem to have been unexpectedly neanthropic, except for the morphology of the symphysis, and certain regions of the horizontal ramus. In the former, attention has already been directed to the fact that the symphysis, reconstructed in fig. 14, is only a representation on an enlarged scale of that characterizing the juvenile jaw, a circumstance which was unavoidable at the time the reconstructions were drawn, and which is indicated by interrupted lines on the latter.

The maximum thickness of the horizontal jaw ramus in *Sinanthropus* occurred on a level opposite the distal border of M2. This is a feature in which the jaw closely resembles that of *Palæoanthropus* (*H. heidelbergensis*), but differs sharply from more modern types. In typical neanthropic modern jaws the area of greatest horizontal thickness is usually represented by a quite circumscribed bulge, which, when all three molars are functional, usually occurs opposite or mesial to the mid-diameter of M2, the thickness of the ramus diminishing sharply both in front of and behind this point.

The two limbs of the lower dental arcade diverge from one another in the adult *Sinanthropus* jaw to a greater degree than in that of *Palæoanthropus*, and in further contrast to the latter form, the inter-canine incisor region, arcs outward to a greater degree in *Sinanthropus* than in *Palæoanthropus*. In the greater total length of its lower dental arcade the latter form also differs from *Sinanthropus*.

The inferior rameal margin of the jaw both in the adult and in the immature developmental stage was evidently quite definitely sinuate in its outline in *Sinanthropus*. In this respect both recall, on a less exaggerated scale, the outline of the lower border of the jaw of *Palæoanthropus*. As in the latter, in both adult and juvenile *Sinanthropus* jaws the vertical height of the horizontal ramus tends to reach a maximum behind the level of Pm1 and dm.1 respectively.

The primitive feature of multiple mental foramina obtains in the three *Sinanthropus* jaw fragments in which this region has been preserved (Locus A, B, and G1 jaws). In each of the adult fragments of the latter species (Locus A and G1 jaws) below the mental foraminal region there is to be observed a somewhat circumscribed and prominent roughened area representing the site for muscular attachment of the platysma-quadrangularis sheet, *mm*, figs. 7 and 11.

Skull.

Though numerous crushed and isolated fragments of the skull vault had been discovered earlier in the material removed from *Sinanthropus* Locus B (Black, 1929, *a*, *b*, *c*), it was not until Mr. Pei's remarkable discovery of the adolescent *Sinanthropus* cranium (Locus E skull) on December 2, 1929, that material for accurate and extensive study became available (BLACK, 1930, *a*, PEI, 1930). The following summer, while material obtained the previous October from *Sinanthropus* Locus D was being prepared, uncrushed fragments (Locus D skull) were recovered from which it was possible to reconstruct, by the simple process of matching broken edges, a second and adult skull (BLACK, 1930, *c*). A full description of the Locus E *Sinanthropus* cranium in comparison with the Locus D skull has subsequently been published (BLACK, 1931, *a*). In the present report therefore it will only be necessary briefly to recall some of the more interesting morphological features characterizing the skull of *Sinanthropus* before considering their probable phylogenetic significance.

General Morphology of Locus E. Skull.—In the accompanying figs. 15 to 20 the six normæ of the adolescent Locus E skull in Frankfort orientation are illustrated in

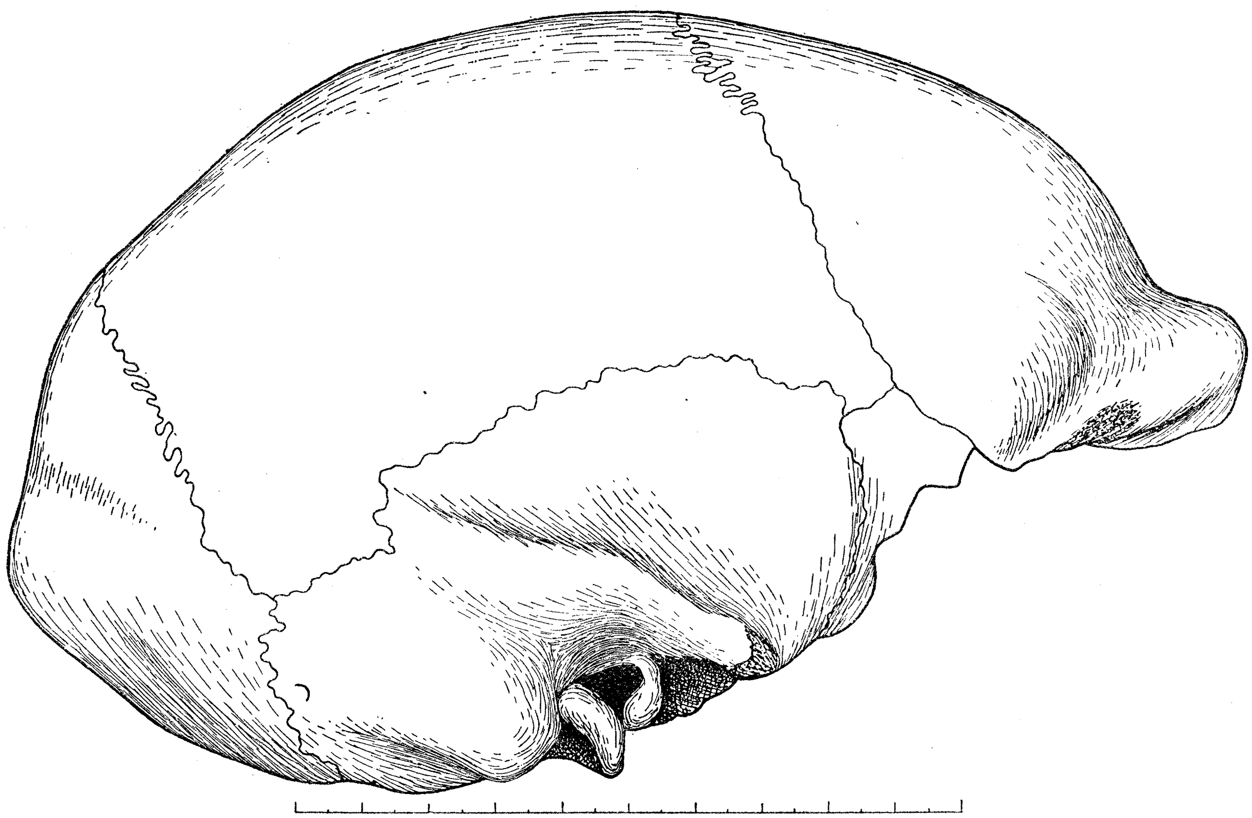


FIG. 15.—Dioptrographic drawing of left norma lateralis of *Sinanthropus* Locus E skull in Frankfort orientation. Natural size. (*Cf.* BLACK, 1931, *a*, fig. 1.)

dioptrographic outline at natural size, since heretofore no such dioptrographic drawings have been made available. The outstanding features of its general morphology may there be recalled at a glance. The highly developed and prominent torùs supraorbitalis, the characteristically medially sloping parietal calvarial outline with well-localized parietal eminences, the pyriform or rounded pentagonal outline of the calvaria behind the orbital torus, and the peculiarly significant morphology of the temporal region, are all evident. These outstanding features may also be noted even at the reduced scale of the photographs reproduced in Plate 10.

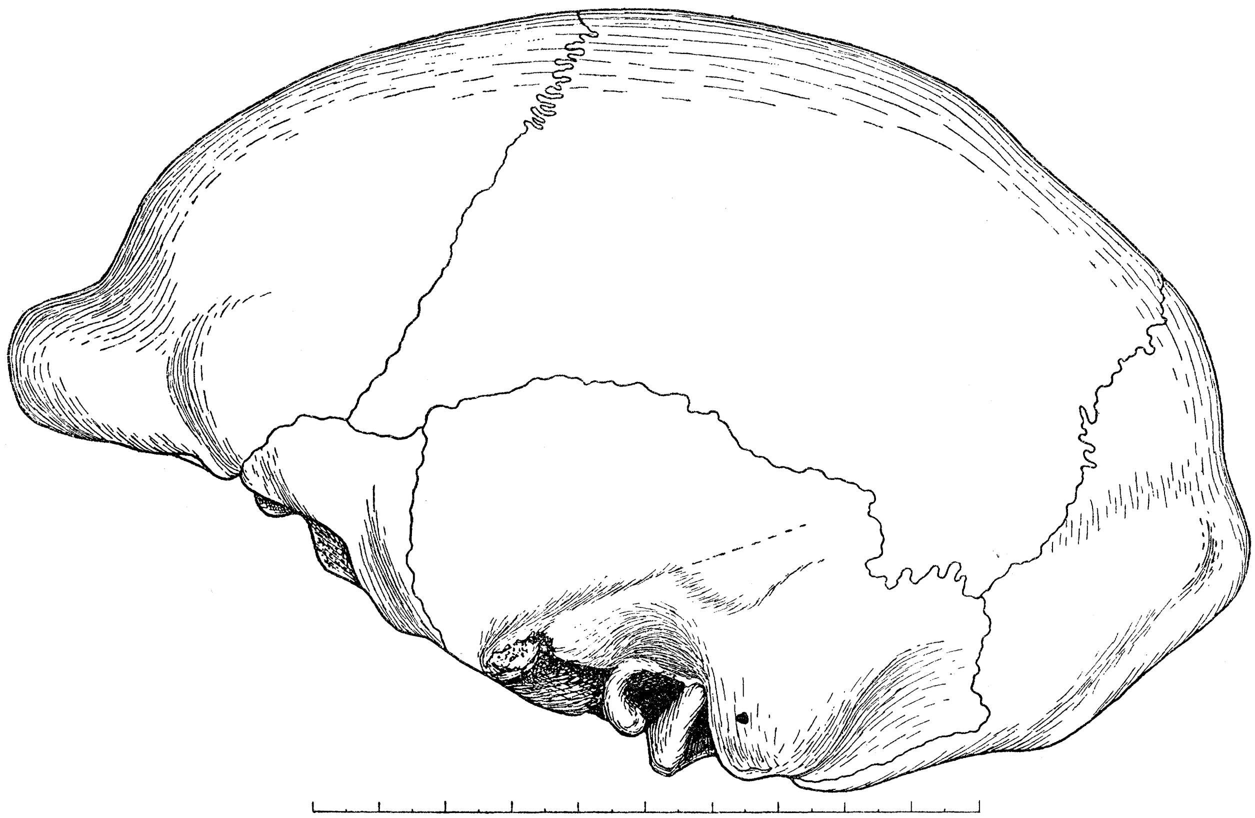


Fig. 16.—Dioptrographic drawing of right norma lateralis of *Sinanthropus* Locus E skull in Frankfort orientation. Natural size. (*Cf.* Black, 1931, *a*, fig. 2.)

The low massive mastoids, bounded posteriorly by the asymmetrical digastric fossæ and medially by symmetrically developed low transverse ridges lying behind the stylo-mastoid foramina, may be distinguished in fig. 18. The low transverse ridges medial to the mastoid proper (crista mastoidea medialis) represent regions into which extend large medial prolongations of the mastoid air-cell system.

The tympanic element is of peculiar interest and importance since its morphology differs so strikingly from that of modern hominids. It is a massive bony structure divisible into anterior and posterior moieties by a natural cleft along the floor of the external auditory meatus. The anterior tympanic moiety rises abruptly from the Glaserian fissure and presents a rounded surface towards the glenoid fossa which it limits posteriorly. The posterior moiety is developed to form a prominent transversely directed crest which passes inwards towards the posterior wall of the carotid canal in front of the stylo-mastoid foramen. There is no trace of a styloid process.

The tuberculum articulare and the glenoid fossa on both sides are almost completely preserved. A small triangular hole is broken through the fundus of the right mandibular fossa. The latter themselves are characteristically hominid in form and relations.

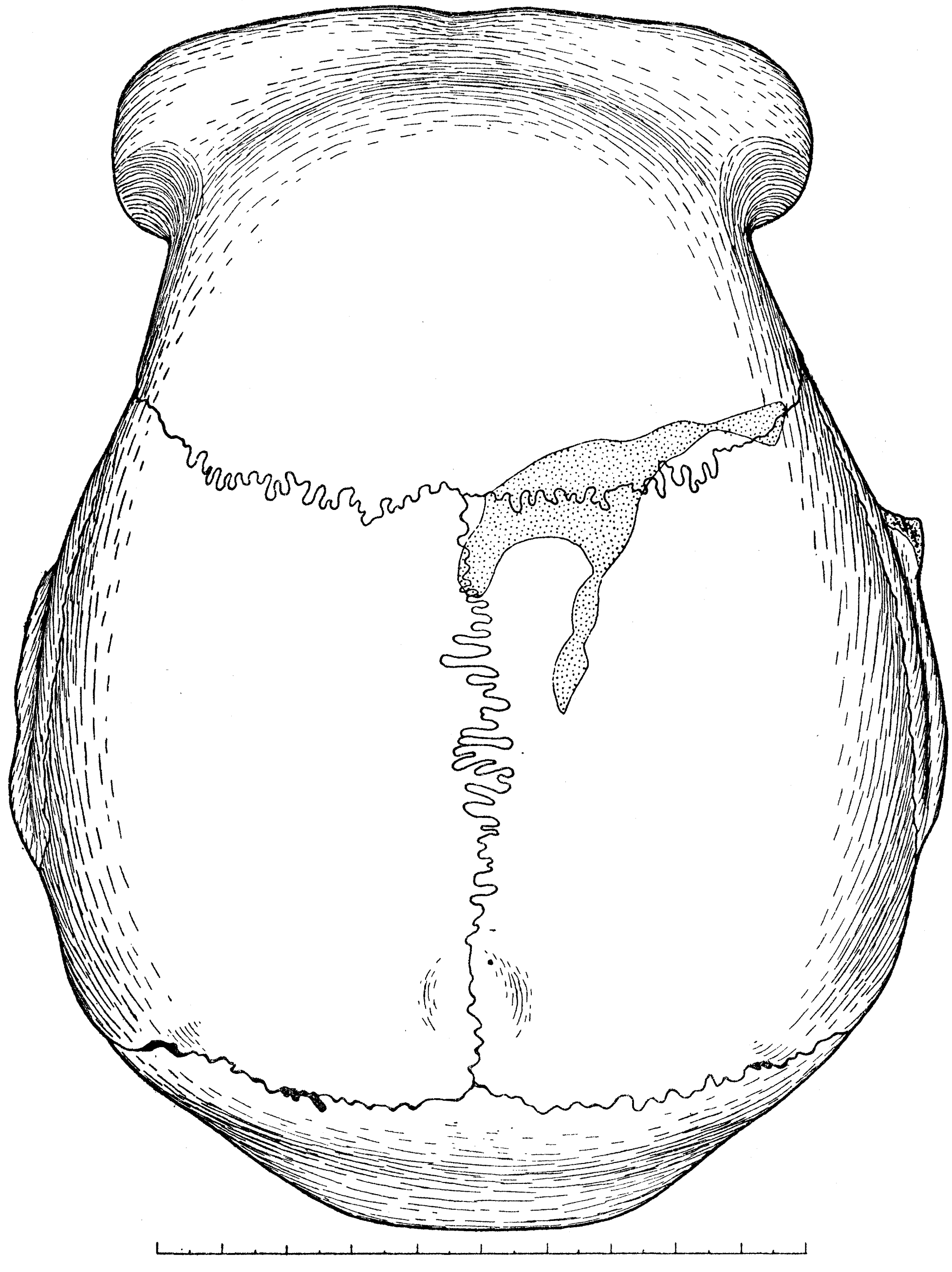


FIG. 17.—Dioptrographic drawing of norma verticalis of *Sinanthropus* Locus E skull in Frankfort orientation. Natural size. (*Cf.* BLACK, 1931, *a*, fig. 3.)

Locus E and D Skulls Compared.—Fig. 21 A and B being drawn to the same reduced scale enable a rapid comparison to be made of the Locus E and D skulls in section.

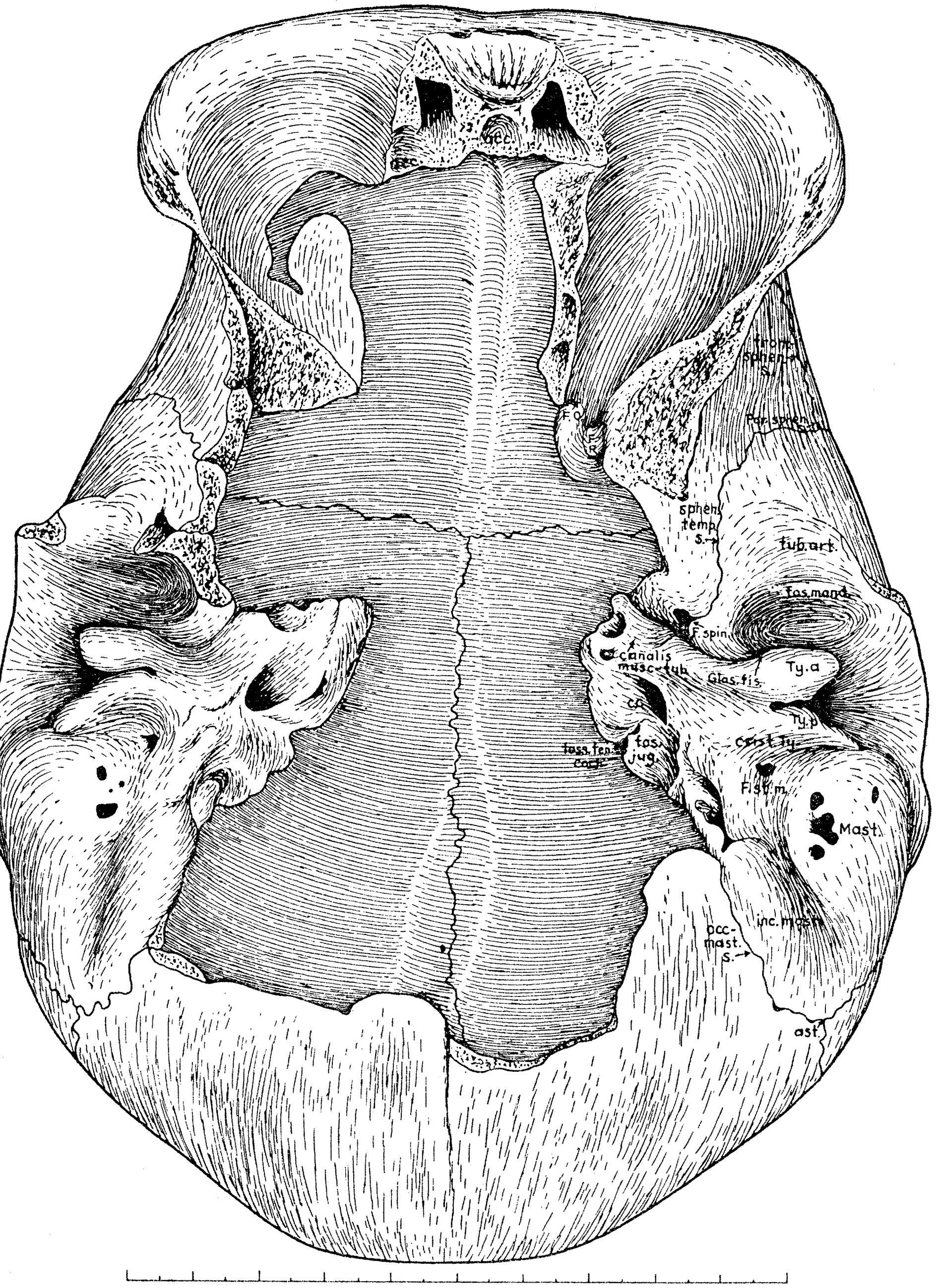


FIG. 18.—Dioptrographic drawing of norma basalis of *Sinanthropus* Locus E skull in Frankfort orientation. Abbreviations : *acc*, accessory frontal sinuses ; *ast.*, asterion ; *canalis musc. tub.*, opening of Eustachian canal ; *c.c.*, opening of carotid canal ; *crist. ty.*, tympanic crest ; *F.O.*, site of optic foramen ; *fos. fen. coch.*, fossula fenestræ cochleæ ; *fos. jug.*, jugular fossa ; *fos. mand.*, glenoid fossa ; F.R., site of foramen rotundum ; *front. sphen. s.*, fronto-sphenoid suture ; *F. spin.*, foramen spinosum ; *F. st. m.*, stylo-mastoid foramen ; *Glas. fis.*, fissura petrotympanica ; *inc. mast.*, digastric fossa ; *Mast.*, mastoid process ; *par. sphen. s.*, parieto-sphenoid suture ; *sphen. temp. s.*, spheno-temporal suture ; *tub. art.*, tuberculum articulare ; *Ty. a.*, anterior tympanic moiety ; *Ty. p.*, posterior tympanic moiety, Natural size. (*Cf.* BLACK, 1931, *a*, fig. 4.)

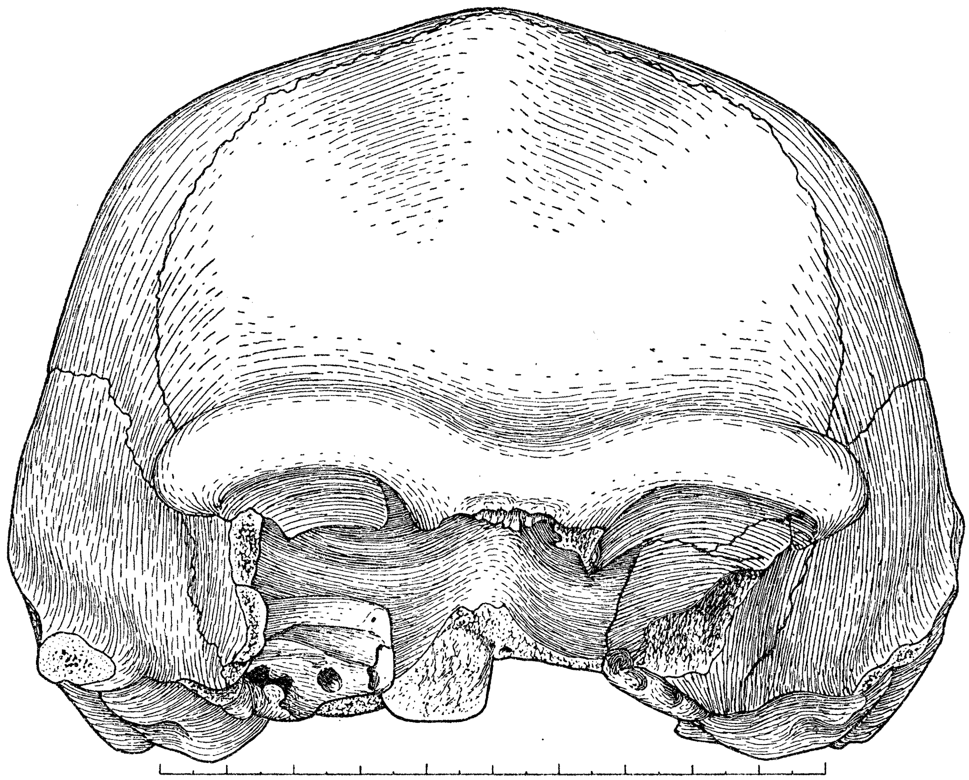


FIG. 19.—Dioptrographic drawing of norma frontalis of *Sinanthropus* Locus E skull in Frankfort orientation. Natural size. (*Cf.* BLACK, 1931, *a*, fig. 5.)

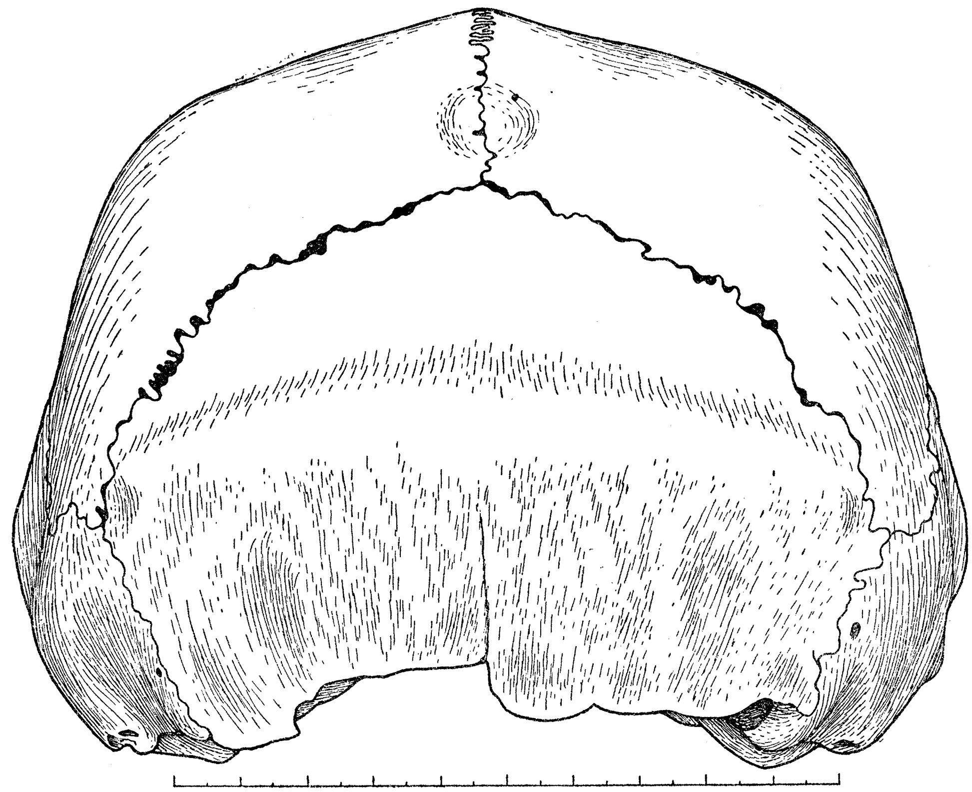
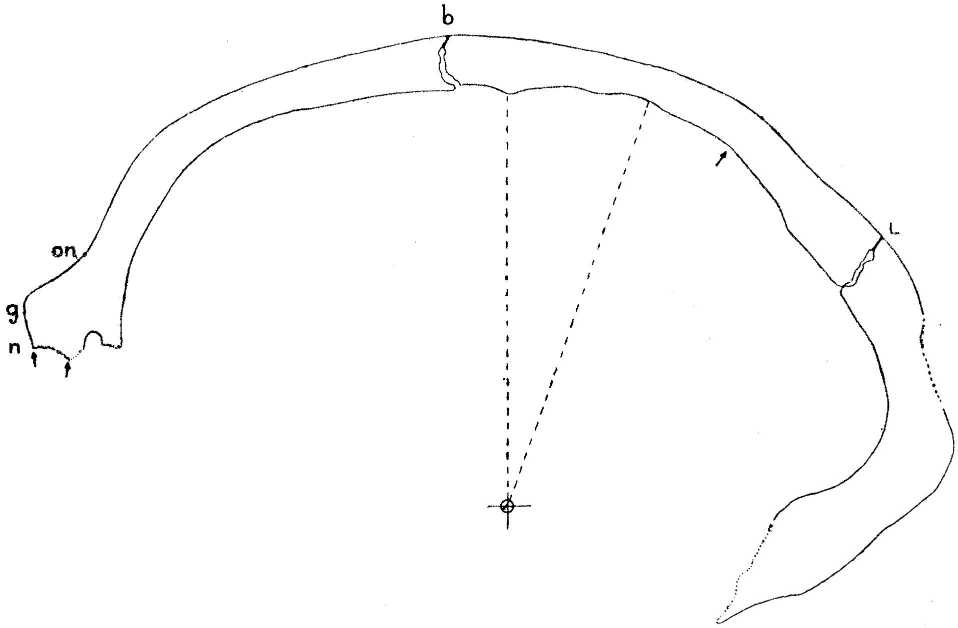
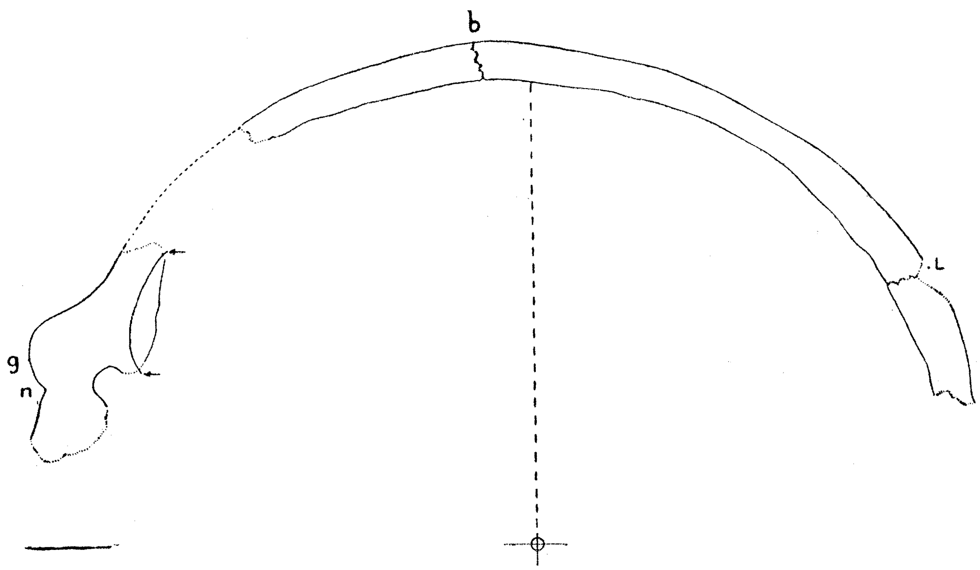


FIG. 20.—Dioptrographic drawing of normal occipitalis of *Sinanthropus* Locus E skull in Frankfort orientation. Natural size. (*Cf.* BLACK, 1931, *a*, fig. 6.)



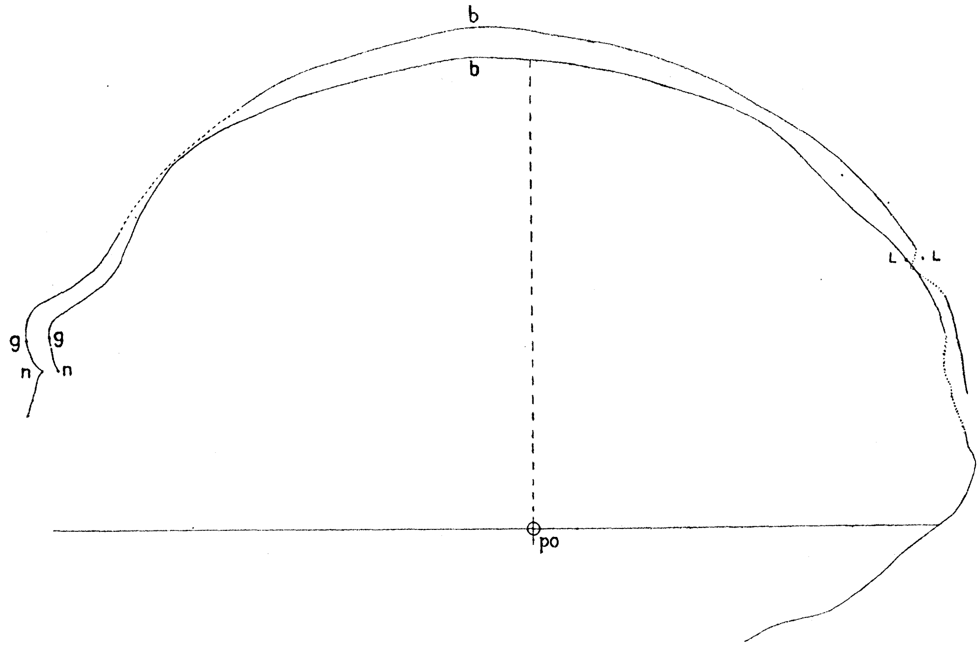
A. Locus E *Sinanthropus* skull—median sagittal section in Frankfort orientation.



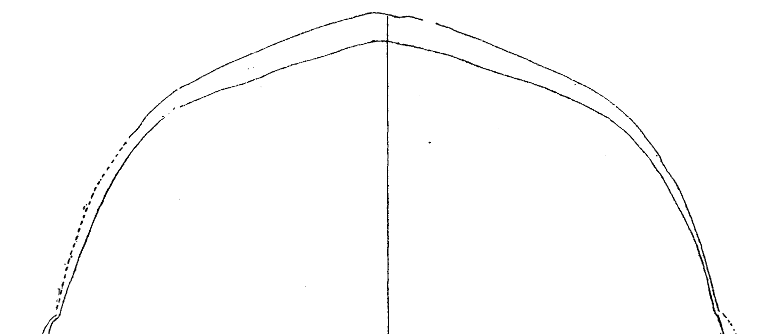
B. Locus D *Sinanthropus* skull—median sagittal section in approximate Frankfort orientation.

FIG. 21.—Abbreviations: *b*, bregma; *g*, glabella; L, lambda; *n*, nasion; *on*, ophryon. The single arrow in *A* points to the level opposite which the right parietal foramen opens into the longitudinal sinus; the two arrows in *A* below the nasion indicate the extent of naso-frontal contact, the frontal spine being broken off at its base behind the arrows; the arrows in *B* point to the extremities of a curve representing the projected outline of the parasagittal endocranial contour of the frontal bone to one side of the crista frontalis. Reduced × 2/3 natural size.

The Locus D specimen is manifestly the larger of the two, but in the relative thinness of its walls is of much less massive build. A more accurate idea of the relative size of



Medial sagittal craniograms of *Sinanthropus* skulls—larger outline Locus D, smaller Locus E skull.



Interporial coronal craniograms of *Sinanthropus* skulls—larger outline Locus D, smaller Locus E skull. Norma frontalis view.

FIG. 22.—Abbreviations as in fig. 21. Locus E craniograms in Frankfort orientation; Locus D contours in approximately similar orientation. The restored portions of the Locus D coronal contour are drawn in interrupted lines. Reduced × 2/3 natural size.

these two skull specimens may be had by reference to fig. 22 A and B. The latter represent reduced scale comparative diagraphic craniograms of the two skulls in

Frankfort orientation, respectively in the mid-sagittal and porion coronal planes. It is evident from these comparisons that though the two specimens differ somewhat in size, they present certain fundamental similarities of outline which without doubt identify each as representative of the same well differentiated type.

Craniographic comparisons with Forms other than Pithecanthropus.—In fig. 23 the mid-sagittal craniograms of a number of widely divergent types have been compared on the nasion-gamma base, with the left portion vertical of each coinciding. In the original of this drawing, the craniogram of the *Sinanthropus* Locus E skull and the

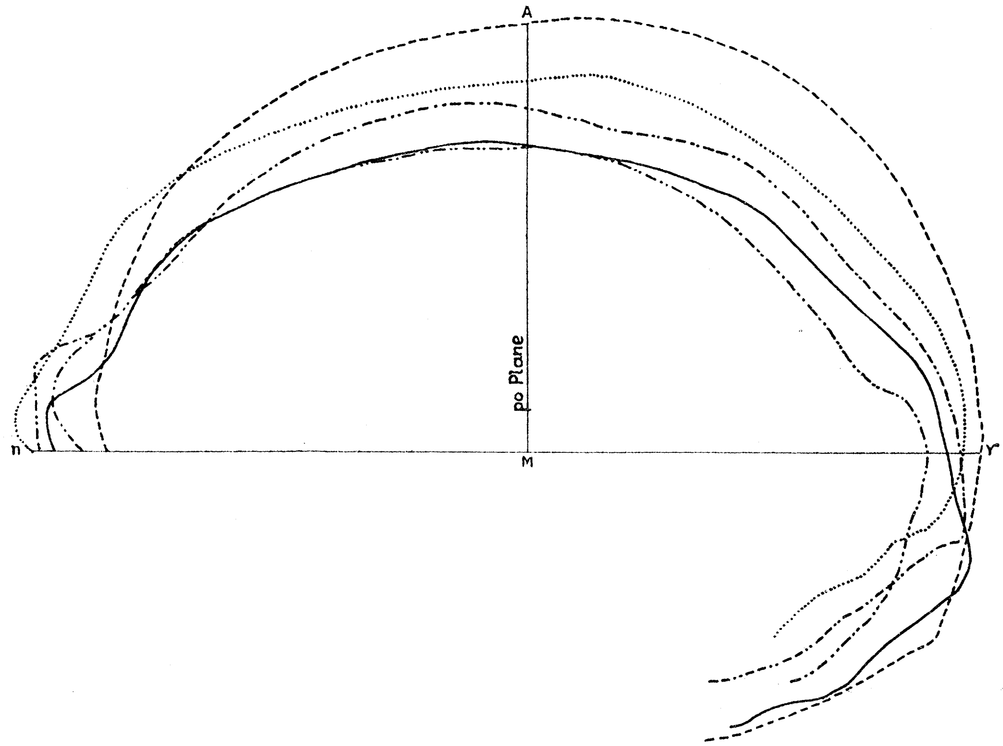


FIG. 23.—Abbreviations: *A*, apex; *M.*, mid-point of interporial diameter; *po. Plane*, interporial vertical plane; $n - \gamma$, nasion-gamma plane. Reduced × 2/3 natural size.

Comparison of left mid-sagittal craniograms on varied scale on n—r orientation. n—L skull diameter in all being made approximately equal. —— *Sinanthropus* Locus E skull, nat. size; – – – N. China ♂ type, nat. size; · · · La Chapelle, reduced; — — · · — — Rhodesian, reduced; — · · — Gorilla juv., much enlarged.

North China type contour were superposed at natural size. The La Chapelle-aux-Saints and the Rhodesian contours were then reduced and that of the juvenile gorilla enlarged, till in each the nasion-lambda length equalled that of the *Sinanthropus* specimen. The outlines thus obtained by enlargement and reduction were finally superposed upon the *Sinanthropus* and North China contours. In the present report the illustration is shown at a reduced size.

The relations portrayed in fig. 23 are essentially but visualizations of those which would have been forthcoming had a multitude of relative measurements upon the specimens been made, and then subsequently compared as indices, either in tabular form or by more extended analysis. The reason for the use of a juvenile anthropoid contour in this comparison is obvious since the cranial contours of all anthropoids become progressively more specialized as maturity is approached. The contour used is that of a young gorilla in which, though the first permanent molars had been erupted, the milk dentition was fully functional. The cranial contour of a young orang or chimpanzee would have served the purpose of this comparison equally well, and had the latter been used, its occipital contour above the gamma would have presented a

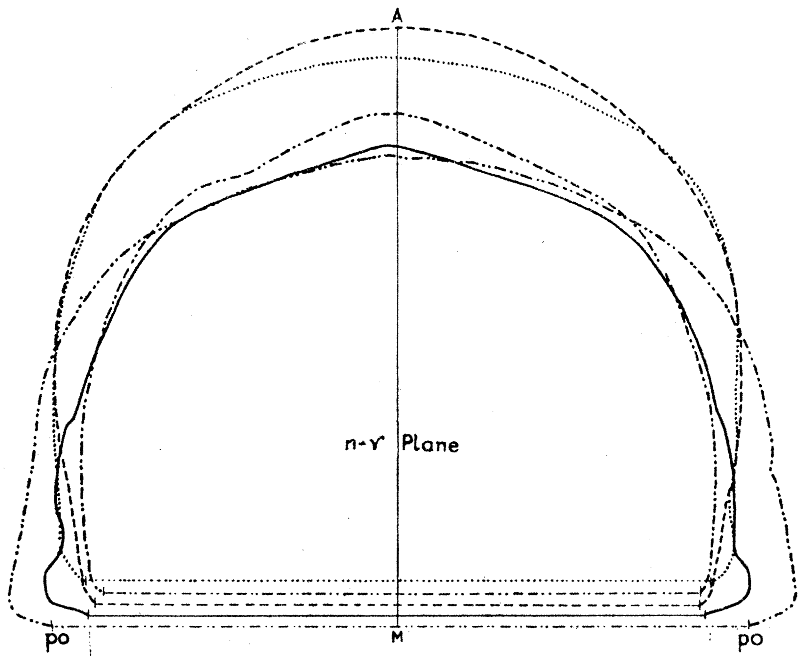


FIG. 24.—Abbreviations: *po*, porion; other abbreviations as in fig. 23. Reduced × 2/3 natural size. Comparison of interporial coroal craniograms on varied scale, orientation in n—γ plane; n—L skull diameter in all being made approximately equal. —— *Sinanthropus* Locus E skull, nat. size; - - - N. China ♂ type, nat. size; · · · · Le Moustier, reduced; — — · · — — Rhodesian, reduced; — · · — Gorilla juv., much enlarged. Norma frontalis view.

more generalized outline than that appearing in fig. 23. In no essential, however, would the significance of this comparison have been affected.

A most instructive comparison results, for the contours evidently arrange themselves in a natural series on the basis of their vault heights as follows: *Gorilla* juv., *Sinanthropus*, Rhodesian, La Chapelle-aux-Saints, and modern North China type. This arrangement of contour levels obtains over the greater part of the frontal and the whole of the apex-gamma arc, and is modified below the latter only on account of the unique sub-gamma occipital development of the *Sinanthropus* contour.

In fig. 24 the comparisons made are again on a varied scale, the illustration being perhaps most comprehensively described as representing a normal frontalis view of the fig. 23, a view, however, in which the Le Moustier has replaced the La Chapelle-aux-Saints outline, since the latter is deformed in the porion coronal plane.

As in fig. 23 the *Sinanthropus* and the North China type contour in the original of fig. 24 were drawn at natural size, the Le Moustier and Rhodesian being on a reduced, and the juvenile gorilla contour on an enlarged scale. The exact alteration of scale size for the Rhodesian, Le Moustier, and juvenile gorilla contours was determined with the aid of proportional dividers. The result for each was the reproduction of a contour at the scale it would have were the nasion-lambda length of the original specimen 170 mm., *i.e.*, identical with that of the Locus E *Sinanthropus* skull.

In this comparison also the contours again arrange themselves in a natural series on the basis of their respective vault heights as follows: *Gorilla*, *Sinanthropus*, Rhodesian, Le Moustier, and North China type contour.

From this comparison also most interesting additional information emerges regarding the position of the porion horizontal relative to the nasion-gamma plane in the contours compared. It is evident that the interporial, as compared with the nasion-gamma, plane is relatively lowest in the gorilla and highest in the Le Moustier contour. The series thus arranges itself on the basis of this criterion from above downwards as follows: Le Moustier, Rhodesian, North China type, *Sinanthropus*, and gorilla. In this it is probably significant that the modern type remains intermediate in position, implying as this does that in this feature the Neanderthal is the most specialized of the four hominid types compared. *Sinanthropus*, on the other hand, would seem to exhibit in this feature a stage well advanced beyond that of the anthropoid in the neanthropic (*i.e.*, progressive) direction.

Craniographic Comparisons of Sinanthropus *and* Pithecanthropus.—In fig. 25 there is reproduced on a reduced scale a comparison of the mid-sagittal skull contours of the adolescent *Sinanthropus* Locus E skull and that of the adult *Pithecanthropus*, the two contours being superposed in the glabella-opisthocranion plane. Reference to fig. 22, in which the Locus E and D *Sinanthropus* skulls are compared, will make it clear that had the larger Locus D contour been used in the fig. 25 comparison, the discrepancy in size between the two adult skull contours would have been much greater. The incompleteness of the lower part of the Locus D outline, however, made its sole use in such a comparison undesirable, and since its inclusion together with that of the Locus E skull in fig. 25 somewhat confused the issue, the adult *Sinanthropus* contour has been omitted from the latter.

In median sagittal section, the contour of the adolescent *Sinanthropus* skull completely encloses that of the adult *Pithecanthropus*, though their respective vertical bregmatic planes (*b*1 and *b*2) fall quite close to one another. A very evident similarity of contour curvature occurs between the respective occipital arcs of the two outlines below the lambda, the torus curve of the one closely resembling that of the other.

Apart from the difference in absolute size, the strikingly higher and fuller frontal and parietal vault curve of *Sinanthropus* constitutes another and most important character serving sharply to distinguish the contour of this form and that of *Pithecanthropus*. There are, however, other important features in which the two contours differ significantly. In fig. 25 the vertical planes in which fall the least frontal diameter (LFB1 and LFB2) and the greatest vault breadth (*eu*1 and *eu*2) have been marked, and it is found that they occupy relatively and absolutely very different positions in the two.

In *Sinanthropus* the plane LFB1 lies 48 mm. in front of the bregma plane (*b*1), the horizontal distance of the latter to the glabella being 75 mm. In *Pithecanthropus* the plane LFB2 lies 40·5 mm. rostral of the bregma plane (*b*2), the latter being 77 mm.

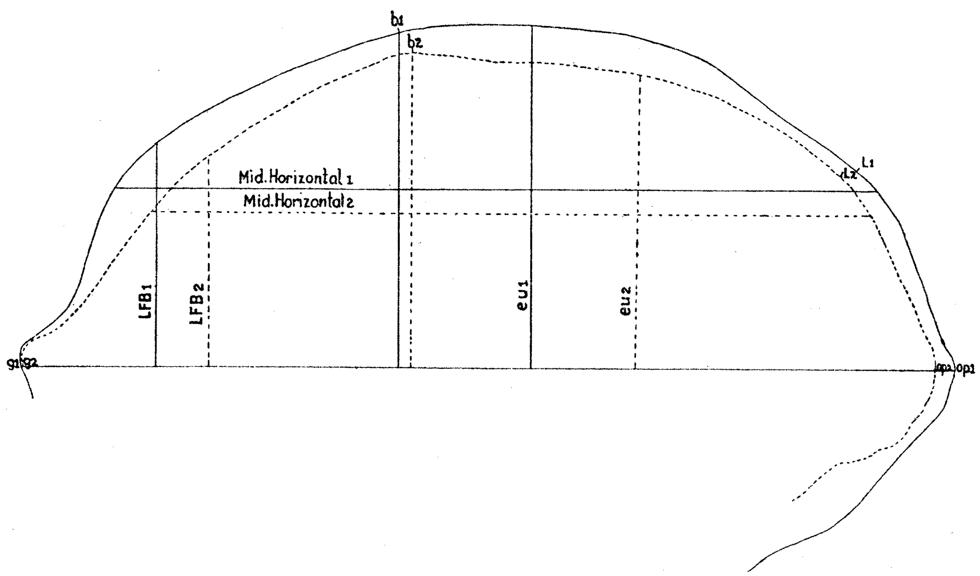


FIG. 25.—Abbreviations: *b*1 and *b*2, *g*1 and *g*2, L1 and L2, *op*1 and *op*2, site of bregma, glabella, lambda and opisthocranion respectively in *Sinanthropus* and *Pithecanthropus* contours; LFB1 and LFB2, site of least frontal breadth coronal contour respectively in *Sinanthropus* and *Pithecanthropus* (*cf.* fig. 26, C); *eu*1 and *eu*2, site of the greatest parietal breadth coronal contour respectively in *Sinanthropus* and *Pithecanthropus* (*cf.* fig. 26, A). Reduced × 2/3 natural size.

Mid-sagittal skull contours in *g-op* orientation—left norma frontalis view. —— *Sinanthropus*; - - - - *Pithecanthropus*.

behind the glabella (*g*2). If these relations be compared in the form of ratios representing the proportion of the *glabella-bregma* length to *bregma-LFB* length, the respective indices are as follows: *Sinanthropus*, 64·0; *Pithecanthropus*, 52·0.

Similarly, if the positions of *eu*1 and *eu*2 be compared, it is found that in *Sinanthropus* (*b*1–*op*1 length = 110 mm.) the *eu*1 lies 26 mm. behind the plane *b*1, while in *Pithecanthropus* (*b*2–*op*2 length = 104 mm.) the *eu*2 falls 44·5 mm. caudal of *b*2. If these relations be compared as indices the following values emerge: *Sinanthropus*, 23·6; *Pithecanthropus*, 42·8.

The foregoing facts serve to demonstrate that, aside from those of absolute size and vault contour, some very significant differences in general proportions also obtain between these two skulls, although they are in many other respects so similar.

The coronal contours of the *Sinanthropus* Locus E skull and that of *Pithecanthropus* are compared at three levels on a reduced scale in fig. 26. The most striking difference

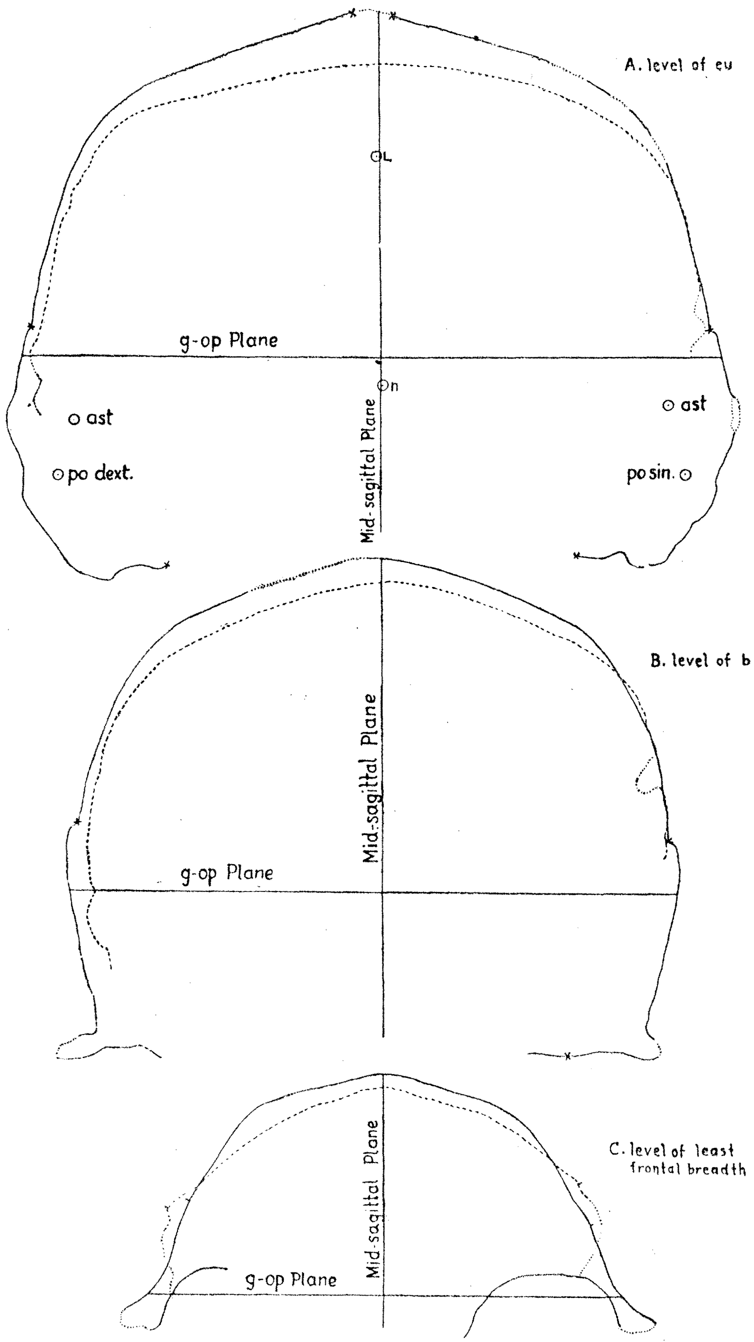


FIG. 26.—Abbreviations: *ast.*, *L*, *n*, *po dext.*, *po. sin.*, projections of the positions occupied respectively by the asterion, lambda, nasion, right porion, and left porion on the *eu* (A) contour of *Sinanthropus*; sutures marked by crosses, positions of superior temporal lines in C indicated by short lines vertical to the respective contours (*cf.* fig. 25). Reduced to 2/3 natural size.

Coronal skull contours in *g-op* orientation—norma frontalis view. —— *Sinanthropus*; - - - - *Pithecanthropus*.

between the coronal contours of the two forms is to be seen in the plane of least frontal breadth, fig. 26, C. Here it will be observed that the *Pithecanthropus* outline is low and broad in contrast to the relatively narrow and highly arched contour of *Sinanthropus*. The approximate position of the superior temporal lines are indicated on the *Sinanthropus* contour, and also on that of *Pithecanthropus*, as closely as could be judged from the cast. In this comparison it is to be recalled that the planes represented are very differently situated with reference to the bregma verticals on the two specimens, compare fig. 25.

The contours of the two specimens at their respective bregmatic levels in fig. 26, B, are similar, though that of *Sinanthropus* is considerably higher, the two being apparently of approximately similar breadth at the squamous suture level.

In fig. 26, A, at the level of the euryon, the two contours are of approximately the same breadth on the *g-op* plane, but over the vault region the *Sinanthropus* contour is much the higher of the two and presents as well a characteristic section of the torus sagittalis. Even making due allowance for the erosion of the outer table of the *Pithecanthropus* skull, the vault contour of the latter in this region is much lower than in *Sinanthropus*. It should again be recalled that the planes represented by these two contours occupy very different positions relative to the bregma verticals in the two crania compared (*cf.* fig. 25).

Endocranial Cast.

The endocranial cast of the adolescent *Sinanthropus* Locus E skull has been the subject of a full report (BLACK, 1933, *a*, *b*) and will be dealt with but briefly here. Perspective diagrammatic outline drawings of the six normæ of this cast are illustrated in fig. 27 where for each drawing the reduced scale in centimetres has been indicated.

Repeated volumetric determinations of the endocranial capacity were made and the volume of the cast accurately determined as 964·4 ± 0·27 c.c., a volume, however, which, though small, would appear to fall well within the lower range of normal variability of this character in modern man. It may be considered probable that endocranial volumes of 1000 c.c. ± 50 c.c. occur in mentally normal individuals among many modern racial groups. In view of his known usage of fire and of his ability in the manufacture of crude stone artifacts it was to be expected that the cranial capacity of *Sinanthropus* would not be found to differ markedly from that of some of his modern successors. On the other hand, the very crudity of his lithic culture (*vide infra*) serves to imply a possible difference in the relative representations within his brain of those cerebral regions whose more advanced development makes possible to the modern savage his superior technique.

The vascular markings are well preserved on the cast, both those of the sinuses and of the middle meningeal vessels. The latter on both sides with but minor exceptions appear to conform essentially to GIUFFRIDA-RUGGERI'S (1912) Type II*a* in which the

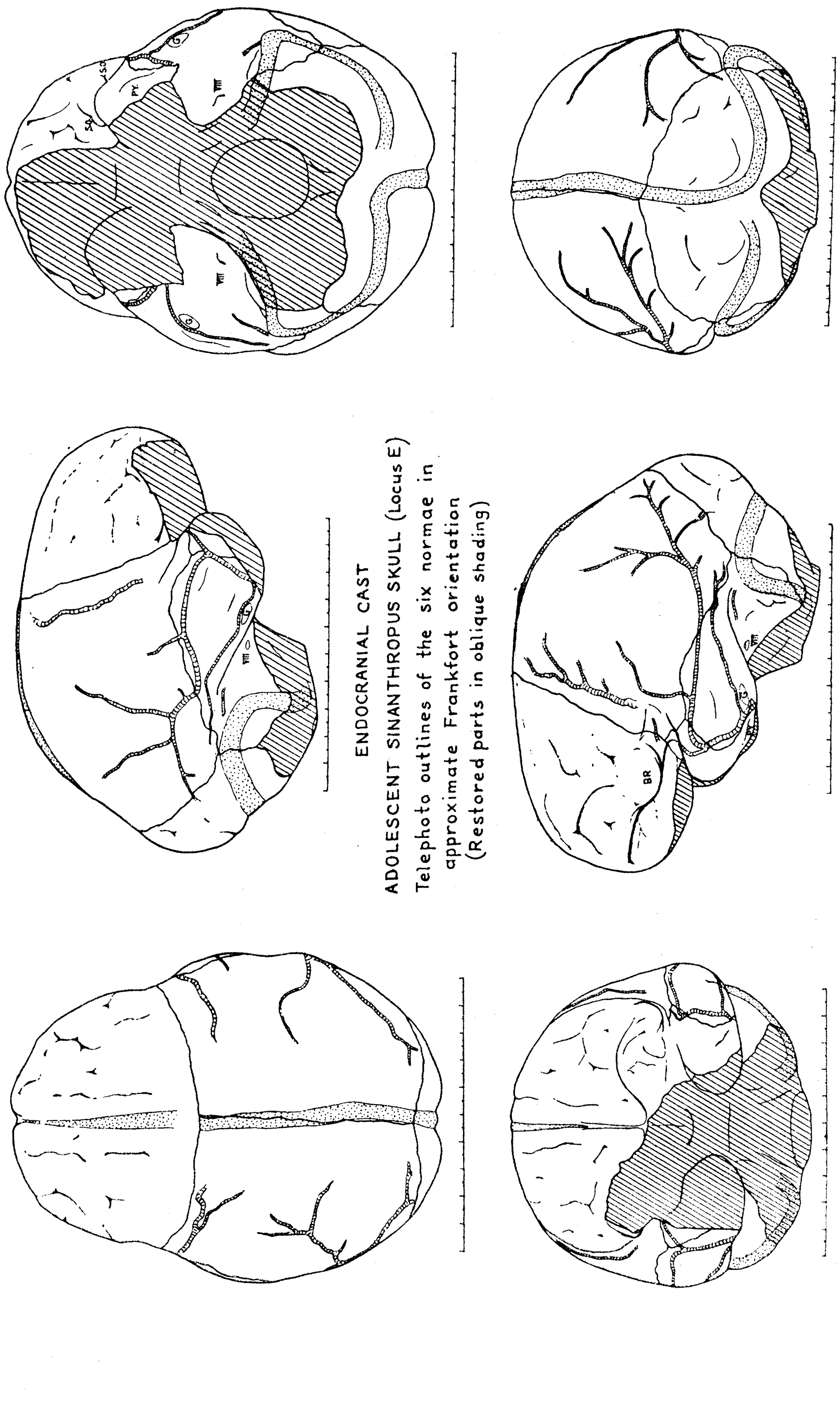


FIG. 27.—Drawings of the Locus E endocranial cast.

ramus bregmaticus is a well-marked unit which with a main ramus lambdicus arises from the common vertical branch, practically on the spheno-temporal border.

The cast displays evident though slight asymmetries which for the cerebellar region indicate an excess in size of the right over the left hemisphere. In the cerebral region the reverse condition obtains, the obvious inference being that the individual was right-handed. The latter conclusion is of interest in view of the independent earlier observation by TEILHARD and PEI (1931) that among the lithic artifacts from the *Sinanthropus* deposit not a few bore evidence of being handled with the right hand.

A consideration of the unique morphology of the parts about the Sylvian depression leads to the conclusion that in *Sinanthropus,* owing to the unequal and peculiar development of the four cerebral operculæ, the anterior insular region was most probably exposed.

The extraordinarily marked development of the opercular portion of the inferior frontal region on the left side in *Sinanthropus* is particularly to be noted in view of the known location in that region of the modern brain of the motor speech centre. Thus the peculiar development of BROCA'S convolution in the brain of *Sinanthropus* provides weighty evidence in favour of the probability that this form was indeed provided with a cerebral mechanism for the elaboration of articulate speech.

Some confusion has arisen owing to the fact that a full discussion of the cerebral sulcal pattern as interpreted from some endocranial cast markings has been omitted in the first descriptions of the latter (BLACK, 1933 *a*, *b*), the inference being that their significance was entirely obscure. Detailed discussion of these markings from the point of view of anthropological neurology has not yet been published. It is expected, however, that such a study will follow in due course as soon as an accurate endocranial cast has been prepared from the adult Locus D skull, the latter specimen at present being in process of complete reassembly of its constituent fragments. Meanwhile, it may be said of the *Sinanthropus* Locus E endocranial cast that the evidences of sulcal pattern there preserved are such as to leave no doubt whatever as to the entirely hominid status of the brain in *Sinanthropus*. The latter presents indeed a number of interesting primitive generalized features, but these are essentially hominid, not anthropoid in character.

Upper Extremity of Sinanthropus.

Os clavicula.—In July, 1931, while excavating Cultural Zone C (Quartz Horizon 2) of the Kotzetang, Mr. W. C. PEI recovered a number of additional *Sinanthropus* fossils, the site of these discoveries becoming thus known as *Sinanthropus* Locus G. Among this *Sinanthropus* material was included a moderately mineralized and deeply pigmented fragment of a clavicle (BLACK, 1931, *e*).

The specimen comprises the greater part of a well-formed left clavicle lacking the sternal epiphyseal articular portion and the acromial fourth of the bone. The superior, anterior, inferior, and posterior aspects of this specimen respectively are here illustrated in Plate 12.

The fragment represents a stoutly made bone with characteristic and well-marked muscular and ligamentous markings, essentially similar in all respects to those of modern human clavicles of similar robustness. The m. subclavius groove is well marked, and the roughness for the attachment of the m. pectoralis major along the greater part of the preserved anterior margin of the bone is similarly evident. There is a slight groove marking the antero-inferior surface of the bone just medial to its broken acromial end, the lateral margin of the groove apparently marking the medial margin of the deltoid tubercle.

Judging from the character of the broken sternal end of the bone, it is probable that the individual from which it was derived was of adult age. The maximum length of the entire bone would appear to have been approximately 15 cm. which would be about the average length of an adult North China male clavicle. As so frequently happens among the latter bones, the rhomboid impression for attachment of the costo-clavicular ligament in the *Sinanthropus* specimen is markedly developed and moderately pitted (BLACK, 1925, p. 84).

Os lunatum.—Among the material excavated from *Sinanthropus* Locus B in 1928 and brought to Peking for preparation Dr. BIRGER BOHLIN recovered the greater part of a left semilunar wrist bone which is undoubtedly to be referred to the genus *Sinanthropus.* The six normæ of this specimen are illustrated here in Plate 12.

Most of the proximal articular surface (fig. 2*a*, Plate 12) of the bone is well preserved, though its anterior edge is somewhat chipped. Distally, the anterior part of the os capitatum articular surface likewise is broken (fig. 2*b*, Plate 12). Erosion is marked over the anterior surface of the specimen (fig. 2*d*, Plate 12) and chipping likewise extends somewhat on to its radial navicular surface (fig. 2*e*, Plate 12), as well as upon the ulnar surface for articulation with the os triquetrum (fig. 2*f*, Plate 12). The dorsal non-articular surface of the bone is perfectly preserved (fig. 2*c*, Plate 12).

The specimen itself is but very slightly mineralized and, like other material from the Locus B site, is of a characteristic light buff colour. As may be seen in Plate 12, the size and proportions of the bone are in all respects similar to those of the os lunatum of modern man. In the latter and in *Sinanthropus,* the os lunatum element of the carpus differs characteristically both in proportions and in size from the corresponding wrist element of modern adult anthropoids.

Radius fragment of questionable origin.—This interesting specimen was brought to Peking from Choukoutien in the autumn of 1927 in a large package of fossils from that area, of somewhat heterogeneous origin. These fossils were then set aside for future preparation and it was not until 1932 that the latter work was completed. Among the material thus acquired, this radius specimen bore a label to the effect that it had been purchased from a local workman and was said to have been derived from Choukoutien Locality 3. When prepared it was then relegated by routine to our collection of *Macacus* fossils from that region. On looking over this collection during his visit to Peking last winter, Professor F. WOOD JONES recognized the hominid character of this radius fragment, which was then set aside for further study.

The specimen itself comprises the upper part of a stoutly built, small, right radius, including the head, the tuberosity and some 10 cm. of shaft below the latter. It presents no special morphological peculiarities serving to distinguish it from a modern human radius of similar size, but is mineralized to a degree similar to that characterizing the majority of the *Sinanthropus* specimens recovered from Locus B of Locality 1. To it there is still adherent in places evident traces of the matrix in which it was originally imbedded, and the latter also resembles in all respects the travertine of *Sinanthropus* Locus B.

Up to 1930, when the Geological Survey finally acquired title to the Choukoutien site, considerable difficulty had at times been experienced in preventing access of unauthorized persons to the areas of our Locality 1 excavations ; and on not a few occasions material certainly derived from the latter was subsequently brought in for sale, with the story that it had been found elsewhere. Up to the present, during our own extensive excavations of Locality 3 and other fossiliferous Choukoutien deposits, no *Sinanthropus* material of any kind has been encountered except in Locality 1. We are therefore inclined to believe it to be highly improbable that this fossilized radius fragment was, in fact, originally derived from Locality 3. On the other hand, in view of the circumstantial evidence of its history, the specimen cannot certainly be ascribed to Locality 1, so that its true origin remains obscure.

Lower Extremity of Sinanthropus.

Up to the middle of May, 1933, when the present paper was completed, no fossil fragments of bones unquestionably referable to the lower extremity of *Sinanthropus* had been recovered. However, since 1929, four peculiar and anomalous specimens apparently representing terminal phalanges of the toes of some large plantigrade form have been recovered in the course of examination of material derived from the Locality 1 deposit (Black, 1931, *e*). These interesting specimens have for convenience in reference received Roman numeral designations and are illustrated in Plate 12.

Ossa incerta—anomalous terminal phalanges.—In September, 1929, Mr. W. C. PEI recovered in the laboratory from material removed from the Main Deposit (Locus A) the previous year a curious terminal phalanx, which in my opinion was difficult to refer to any animal other than a hominid form such as *Sinanthropus*. This specimen, now known as *Phalanx I*, is dark brownish red in general tone and is moderately mineralized. Since our museum osteological material for comparison with this interesting specimen was quite inadequate, a cast of the bone was made and sent in October of the same year to the late Professor W. D. MATTHEW with a request for his opinion as to its identity.

Dr. MATTHEW's reply to our enquiry, written on January 2, 1930, confirmed my first impression with regard to the specimen. He wrote as follows : " It certainly is not

Hipparion or tapir or tortoise, the only alternate possibilities that I have been able to suggest; none of them are at all near. *Hipparion* side toes are unsymmetrically trigonal with much higher narrower proximal facet of triangular form, more deeply excavated. Tapir toes are something the same only shorter and stubbier. Tortoise claws are much less flattened, more convex proximo-distally, more pointed toward tip, different quality of bone, less perfect facet surface, etc. This has all the characteristic features of a primate ungual, and among primates nothing but man comes at all near it."

Meanwhile, a number of terminal phalanges of fossil ungulates from Nihowan and elsewhere were obtained for comparison. Disregarding differences of size, some of these probably derived from deer-like forms exhibited evident points of resemblance to *Phalanx I* so once more the question was referred to Dr. MATTHEW. His final opinion on this matter was received in April, 1930, to the effect: "No, I do not think there is any chance of the toe bone belonging to a ruminant."

During the spring of 1930 three additional anomalous terminal phalanges were recovered, *Phalanx II* was derived from Layer 8 of the Lower Fissure, *Phalanx III* and *Phalanx IV* being recovered during the sieving of the last rubbish accumulations remaining from the Lower Fissure excavations of the previous season.

Reverting to a consideration of the first specimen recovered (*Phalanx I*), the following characteristics may be noted: The specimen is depressed dorso-ventrally and elongated, its dorsal surface being somewhat convex both from side to side and proximo-distally. The roughened area of the tuberositas unguicularis encroaches upon the dorsal surface of the bone more widely, while ventrally it is much less developed than in any known hominid. The proximal articular facet is of an irregularly transverse oval outline, and exhibits a faint dorso-ventral division like that commonly characterizing this facet on the terminal phalanx of the thumb in modern man.

It is evident that the positive identification and interpretation of these interesting bones cannot well be established beyond reasonable doubt unless new discoveries throw further light on the subject.

GEOLOGICAL AND PALÆONTOLOGICAL ENVIRONMENT OF *Sinanthropus*.

General Description of the Region and Locality.

Physiographically, the Western Hills (Hsi Shan) represent the eastern margin of a deeply dissected Late Mesozoic platform (fig. 1), attaining altitudes up to and over a thousand metres above sea level, fig. 28. Geologically, the peneplained mass includes the following chief terms: Sinian (Precambrian) quartzites and siliceous limestone; Cambrian shales; thick Ordovician limestone; Carboniferous slates and shales; Triassic sandstone; very thick Jurassic conglomerates, slates, and sandstones, interbedded with several andesite flows; post-Jurassic granites and quartz porphyries.

Near Choukoutien this stratigraphical complex is well represented. Thus, the Jurassic metamorphosed conglomerates and green sandstones form the high mountainous background from which during the rains, torrents of water descend to flood the otherwise usually dry river bed at Choukoutien. A large circular granitic intrusion is to be observed a few kilometres to the north-east of the village, a second and smaller one occurring an equal distance to the south of the latter, fig. 31. Finally, a low Palæozoic anticline forming the foot-hills at Choukoutien itself provides the chief elements both for its economic welfare and for the human palæontological interest of the locality, namely, coal in the Carboniferous slates ; lime and caves in the Ordovician strata.

Character and origin of the Choukoutien deposit.—Of Tertiary sediments only those of the Pliocene are represented in the Choukoutien area though deposits of Eocene age occur to the north in the vicinity of Changhsientien, fig. 28. In the Choukoutien region itself the oldest Cenzoic horizon, probably a Pontian formation, is represented by a level of well-rounded gravels known as the " Upper gravels," at an elevation approximately 70 metres above the present river bed. An intermediate and more extensive formation occurs, consisting of dark red clays which merge at about 8 metres above the river bed into a well-formed conglomerate. Above the latter lies the huge Upper Pleistocene (" Loessic ") erosional fan (BLACK and others, 1933).

In correspondence with these superficial deposits there are to be recognized in this area three subterranean deposits occurring within the cavities of the Ordovician limestone itself in successively excavated systems of fissures. The oldest of these fissure systems is filled with non-fossiliferous sands and gravels corresponding in age to the " Upper gravels." A system of fissures of a somewhat younger horizon and filled with more or less firmly cemented and richly fossiliferous sub-aerial deposits is also clearly to be recognized, corresponding in age to the intermediate formation noted above. These fossiliferous clays and breccias filling the fissures represent the Choukoutien formation proper, and are without doubt of Lower Pleistocene age. Representation within the " fissures system " of the Upper Pleistocene is also evident in a series of empty or but partly filled caves in which occur stalagmites and stalactites not now in an active stage of growth.

The Ordovician limestone at Choukoutien is quarried extensively to serve the numerous lime kilns of the district, and in many of these rock cuttings fossiliferous pockets are to be observed. Most if not all of them occur approximately from 70–80 metres above the river bed and thus correspond roughly to the level of the *Upper gravels*. Up to the close of the field season of 1932, eleven such fissures, designated respectively Localities 1 to 11, fig. 31, have been recognized and their fossiliferous content studied and in part described (PEI, 1931, *a* ; YOUNG, 1930, 1932, *a*). In all the localities the fauna has so far proved to be the same throughout the whole thickness of the deposits, and therefore the Choukoutien formation must be considered as a perfectly homogenous and distinct stratigraphical unit.

The deposit known as Locality 1, which is the only one from which *Sinanthropus*

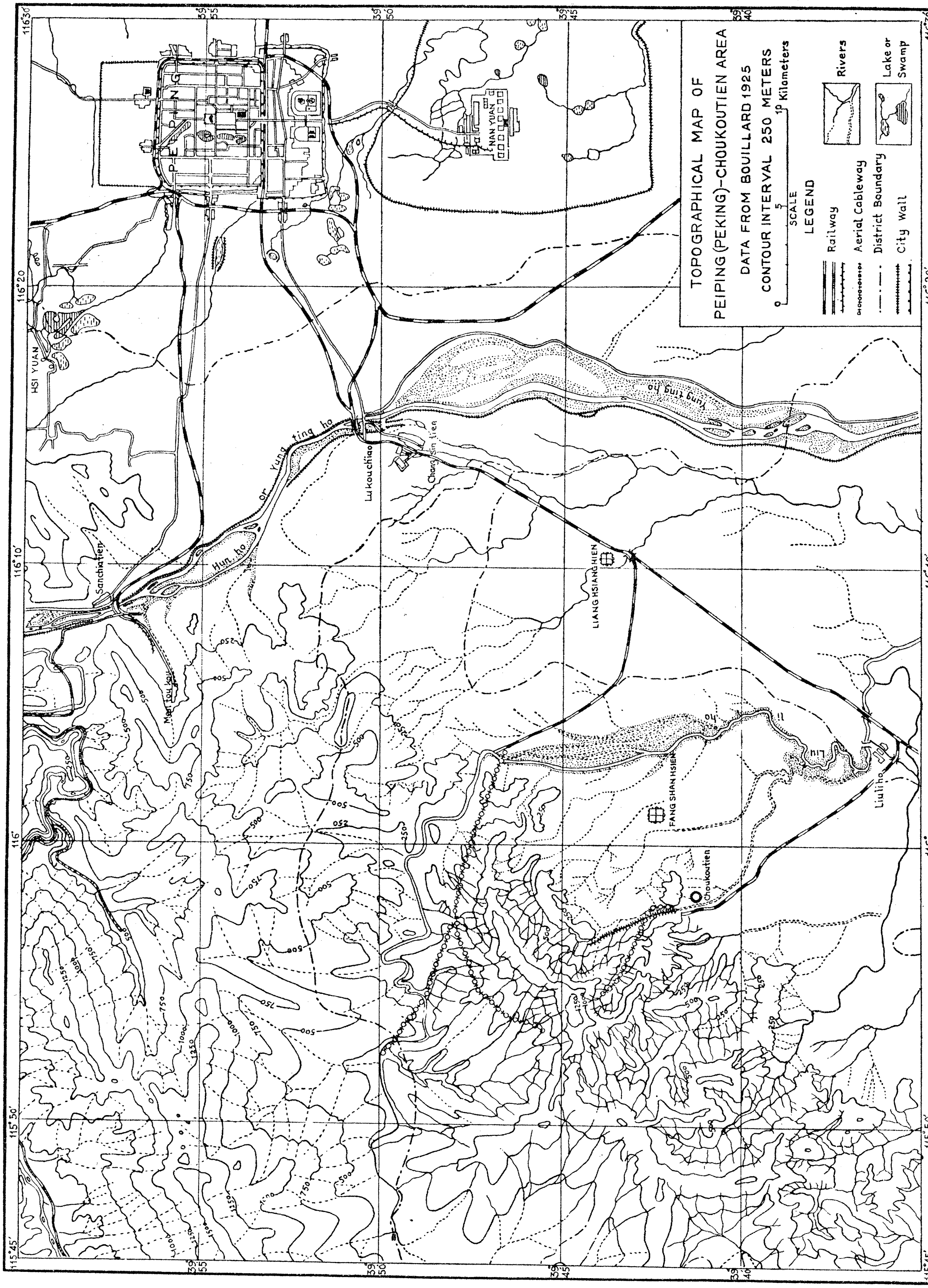


Fig. 28.—Topographic map of Peking (Peiping)—Choukoutien area. Data reduced from map sheets 140, 141, 160, and 161 by M. G. Bouillard, Edition 1925.

skeletal or cultural remains have unquestionably been recovered, is by far the largest and richest of the Choukoutien fossiliferous fissures. This pocket occupies approximately the core of the Ordovician anticline forming the hills in the vicinity of Choukoutien village. The deposit is sufficiently extensive to have formed an effective barrier to the continued development of all the limestone quarries originally started on the north face of the hill in which it occurs. During a prolonged period of its history it must have been largely empty and cave-like. Gradually, however, through weathering action, periodical roof collapse, and the accumulation of detritus, its great cavity became filled with a hard brecciated travertine, the complex formed by the fissured limestone and the cemented breccia finally becoming so hardened that both constituents together have been worn and rounded as a single mass by subsequent erosion.

In the present stage of excavation the deposit as exposed extends east and west over a length of some 175 metres; north and south, at its eastern end, over a breadth of 50 or more metres; while in height opposite the Lower Fissure it rises some 50 metres, fig. 30. Only on its north side can the approximate limits of the whole deposit be gauged at present with any degree of certainty, though even here its lower limit has not yet been reached. On the other hand, in spite of the deceptive appearance presented by a septum-like mass of fallen limestone in the upper part of the deposit, Layer 3, fig. 30, it is perfectly clear that the original top of the formation has been destroyed by past erosion, for the cave deposits without doubt extend above what had earlier been alluded to as the "collapsed roof" (TEILHARD and YOUNG, 1930), and attain to the actual present surface of the hillside above. A striking indication that the Choukoutien fissures have been strongly eroded since the complete formation of their contained deposits is afforded by the fact that a layer of extremely hard travertine, 1 metre in thickness capping the very summit of the hill just to the south of the Main Deposit of Locality 1, is full of the bones of Chiroptera, fig. 30 and Plate 6. A whole superstructure of dissected limestone, now no longer existing, must at one time have existed in this place in the past, in order to explain the presence here in such a situation of this stalagmitic Chiroptera-bearing mass.

In view of these observations it is evident that even in that part which has been preserved the original shape and extent of Locality 1 cannot yet completely be defined. Nevertheless, it has become customary in the field to distinguish by special terms the three following different regions of the deposit, fig. 29:—

The Main Deposit, forming the most central and extensive part of the exposed beds. This part has not been readily accessible for systematic investigation since the first vertical cuttings of 1927–28 were completed.

The Lower Fissure, forming a narrow cleft some 7 metres broad at its widest part, extending northward from the Main Deposit and connected below with a series of caves. This area of the deposit was worked intensively during the field seasons 1929–30.

The Kotzetang, an artificial cave probably excavated very recently within the eastern breccia. With the exception of its northern wall, which is formed of the original limestone, it is bounded an all sides by very hard, firmly cemented breccia. By quarrying a trench in the hard breccia forming the floor of this modern cave in 1931 the deposit was demonstrated to extend downward unchanged to the level of Quartz Horizon 2 (Cultural Zone C).

In general, the deposits of Locality 1 may be described as consisting essentially of a solid mass of hard, red angular breccia, sometimes crowded with fossils to an amazing

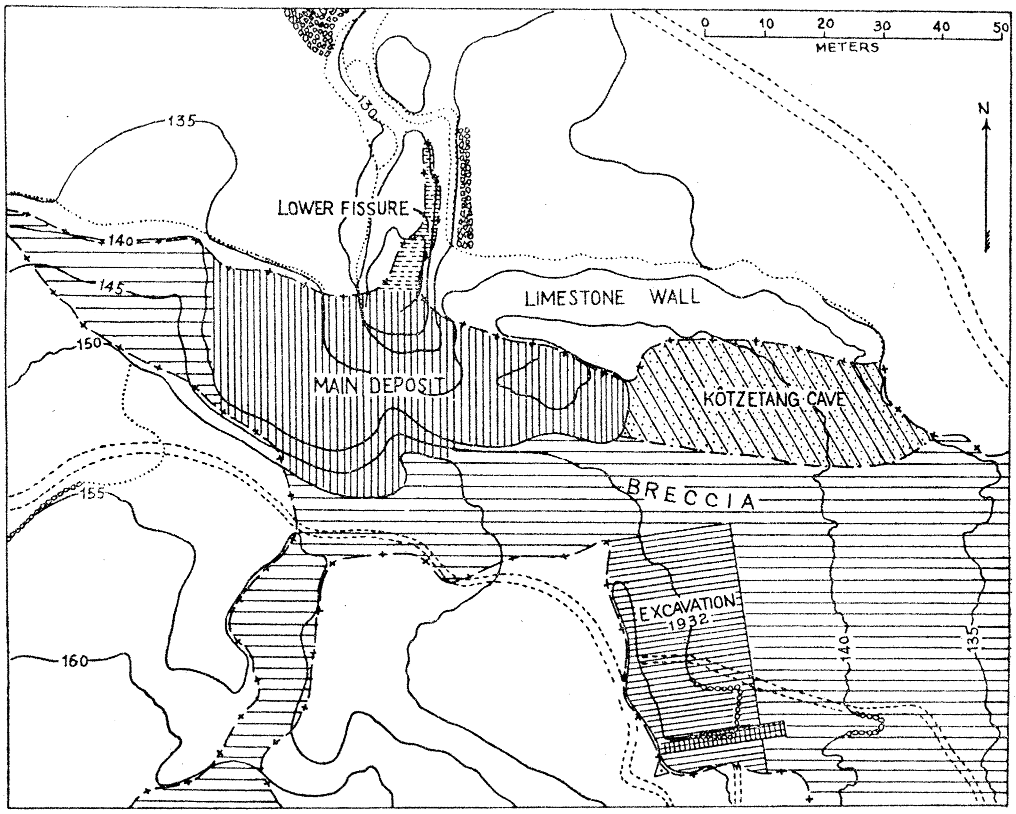


FIG. 29.—Diagram to illustrate the distribution of the areas of excavation in the *Sinanthropus* cave deposit (Choukoutien Locality 1). Modified from BLACK and others (1933), fig. 6, p. 15.

extent. However, this fundamental material is distinctly alternated with several horizontally disposed sandy or ashy layers, so that the whole system forms a regularly stratified deposit. Formations of rounded gravels are entirely lacking throughout the deposit. No detailed description of the stratigraphy is necessary here, and for a comprehensive discussion of the subject reference should be had to the recently published Memoir of the Geological Survey of China (BLACK and others, 1933).

Fauna of the Sinanthropus *Cave Deposit.*

The fossils collected in the Choukoutien cave deposits, especially the mammal remains, are characteristic and numerous. A complete list of the Choukoutien fossil forms so far as they have actually been determined, together with a detailed discussion of their significance is to be found in the Memoir cited above. In the present connection, however, it is desirable briefly to review some of the results of the latter study.

Canidæ.—A rather large wolf, a small "microdon" dog (*Canis* or *Nyctereutes, sinensis*, Schlosser), and slender fox (*Vulpes chikushanensis*, Young) are very common in the Choukoutien deposits.

Bears.—Three different bears occur in Choukoutien: a small one (*Ursus angustidens*, Zd.); and two very large forms, one of them resembling the European *U. spelæus* both in its size and in the strong convexity of its forehead.

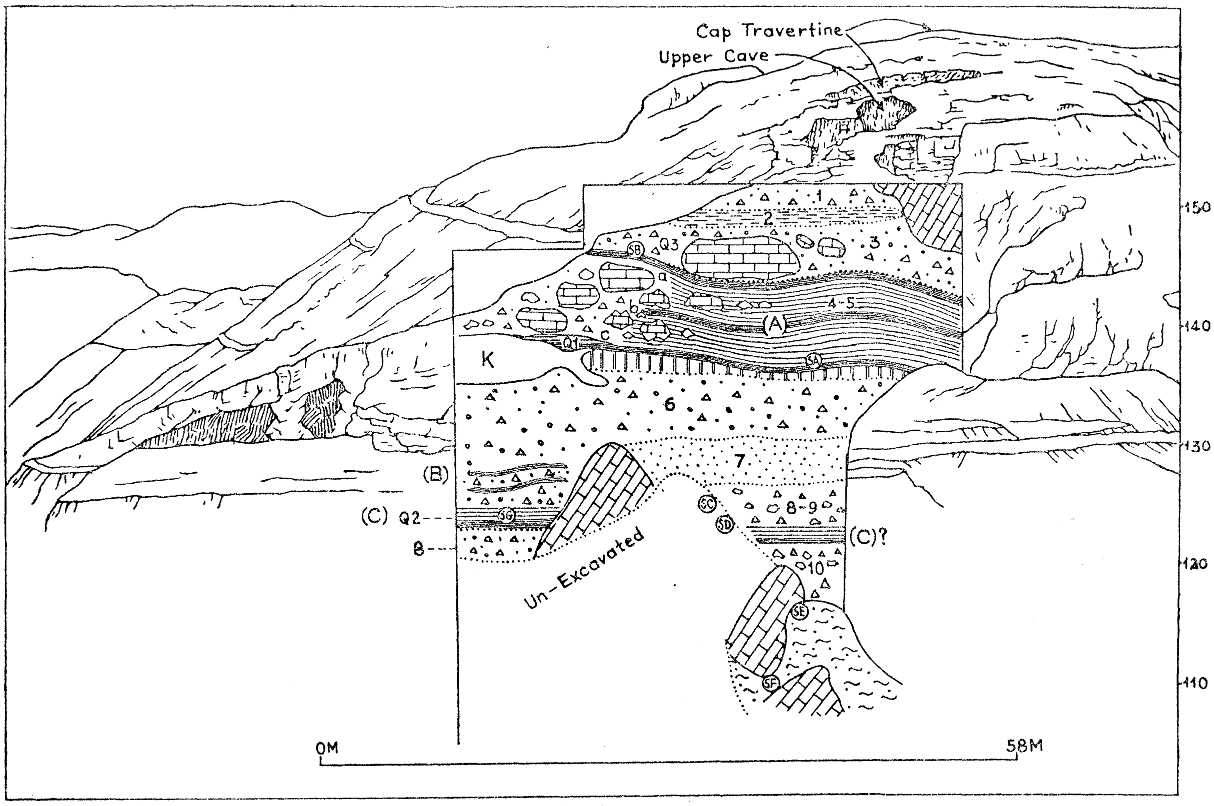


FIG. 30.—Longitudinal east-west section of the *Sinanthropus* cave deposit set diagrammatically in the topographic background of Choukoutien Locality 1 (*cf.* fig. 3; Plates 1 and 2). Redrawn from BLACK and others (1933), fig. 7, p. 16).

Mustelidæ.—This group is represented only by such still existing types as *Mustela, Meles*, etc.

Hyænas.—Hyæna remains are exceedingly numerous, particularly in the lower levels of the deposit. They belong to at least two quite different species, the most abundant type being *H. sinensis*, Ow., which is a very large form.

Cats.—The presence of *Machairodus* is attested by the occurrence of several characteristic specimens of the large-serrated canines, but these remains are particularly rare. At least six different types of true cats also haunted the cave during the times of

Sinanthropus. One was a big animal larger than a tiger, one a true tiger, one a leopard, besides three or four smaller forms.

Rodents.—In addition to a very large series of small rather atypical, modern-looking Muridæ, etc., the deposit has yielded some interesting forms such as *Siphneus*, *Arctomys*, and *Trogontherium*. The *Siphneus* is represented by two or three forms of interest on account of their stratigraphic bearing. The *Arctomys* belongs probably to a still living

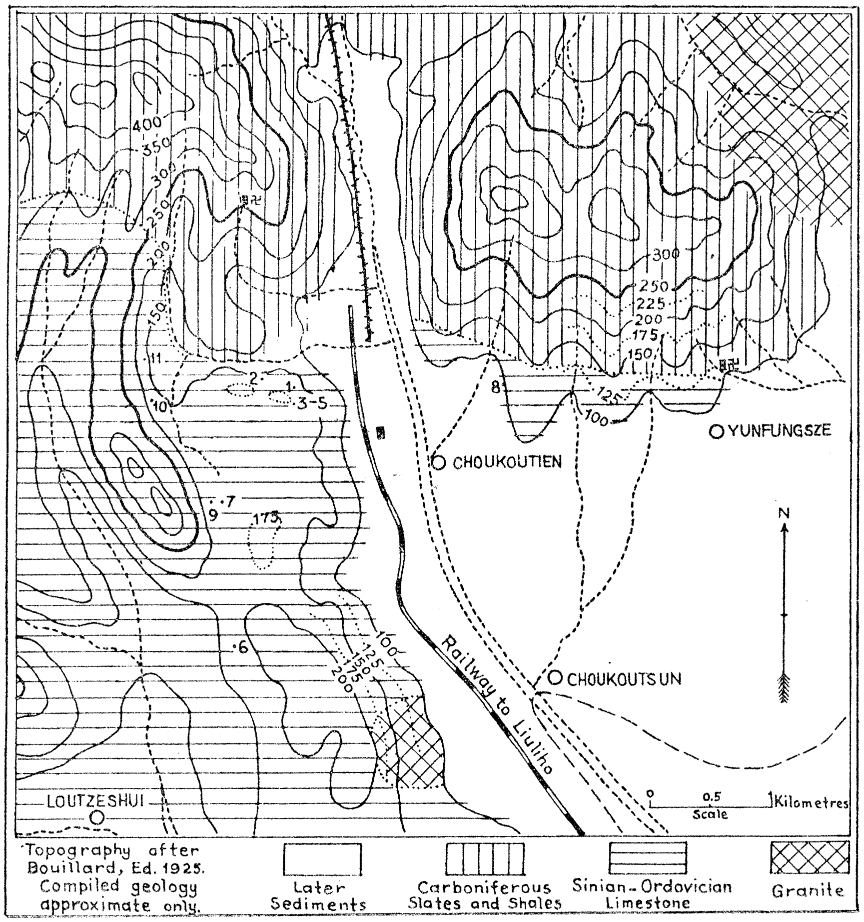


FIG. 31.—Compiled geological map of the Choukoutien area, illustrating also the distribution of the Choukoutien fossiliferous fissure deposits, the latter Localities being indicated by their respective number designations 1 to 11 ; contours in metres (*cf.* fig. 28). Modified from BLACK and others (1933), fig. 2.

species. The *Trogontherium* is of interest because it is an archaic form, extinct before the deposition of the Loess.

Horse.—The Choukoutien horse is a very large form, probably identical with *Equus sanmeniensis*, the first and biggest horse known in North China.

Rhinoceros.—By far the most commonly found rhinoceros in Choukoutien is a *Dicerorhinus*, practically identical with the European *R. mercki*. Another much rarer species is almost if not wholly indistinguishable from the Upper Pleistocene *R. tichorhinus*.

Wild Boar.—(*Sus lydekkeri*, Zd.). This form is very common and is represented by many specimens including fine complete skulls.

Camel.—Very large camels are represented among the material. They belong most probably to the true *Camelus* genus which occurs in China ever since Late Pliocene times.

Deer.—The remains of deer occur abundantly in the Choukoutien deposits. They belong both to the living types *Moschus*, *Hydropotes*, *Pseudaxis* (Sika), as well as to the extinct *Euryceros* group. No traces of *Cervulus*, nor of the characteristically Upper Pleistocene *Elaphus* have so far been observed.

The Euryceroid form (*Euryceros pachyosteus*, Young) is one of the most abundant and characteristic elements of the Choukoutien fauna.

Antelopes.—In addition to a few remains of *Gazella*, the only antelope found in Choukoutien is a fine *Strepsiceros* form, *Spirocerus peii*, Young, the *Spirocerus*, Boule and Teilh., being an extinct genus easily recognizable by the shape of its perfectly straight slowly spiralled horn cores.

Sheep.—In Choukoutien the sheep skulls collected in the *Sinanthropus* cave deposit are identical with those of the living *O. ammon*, though canon bones of a smaller species are also present which may tentatively be referred to the living form *O. nahor*.

Ovibovidæ.—The discovery in the Choukoutien deposit at Locality 9 of an almost complete skull evidently belonging to the *Ovibos* group was rather an unexpected one. So far the latter has not been encountered in Locality 1, the *Sinanthropus* deposit itself.

Bovinæ.—Skulls and bones of a large water buffalo (*Bubalus teilhardi*, Young) are abundantly found in the Locality 1 deposits, associated with a few remains of Bison.

Elephas.—*Elephas* remains are not rare in the *Sinanthropus* Locality where they generally occur in the cultural layers. Unfortunately no complete molar teeth have yet been found, but judging from an isolated lamella, the Choukoutien form almost certainly belongs to the *namadicus* group.

Primates.—Aside from *Sinanthropus*, no other Primate has been encountered in any of the Choukoutien deposits except a *Macacus*, somewhat larger than the living species of North China.

Ostrich.—The ostrich is represented by numerous pieces of eggshell (*Struthiolithus*) chiefly occurring in the cultural layers, and is the only interesting bird recognized in Choukoutien.

As to the palæontological significance of the foregoing assemblage, the conclusion is obvious. In full accordance with the known stratigraphical facts, the Choukoutien fauna fits so exactly between the Late Pliocene (Nihowan) and the Upper Pleistocene Loessic (Sjara-osso-gol) ages that it is not easy to decide to which of them it stands the more closely related. Consequently the Choukoutien formation has broadly to be considered as of Lower Pleistocene age.

Cultural Environment of *Sinanthropus*.

In the present stage of the excavations (Autumn, 1932) three cultural zones, A, B, and C (Black and others, 1933), are recognizable in the massive brecciated formation filling the *Sinanthropus* deposit (Locality 1, fig. 30).

Cultural Zone A.—In the Upper Cultural Zone A there is included the whole (6 metres thick) accumulation of banded yellow, red, and black sandy clay indicated as Layers 4 and 5 in the stratigraphy of the cave. This entire deposit is an ashy one, in which at least three layers containing artificially broken quartz have been located: an upper one *a* (Quartz Horizon 3 of Pei, 1931 *c*) a middle one *b*; and a lower one *c* (Quartz Horizon 1 of Pei).

Cultural Zone B.—The Middle Cultural Zone B is only represented by two thin, but 50 cm. thick, layers of red and black sandy clay—ashy layers—crushed and laminated in the mass of stratified hard coarse breccia in the eastern part of the deposit, Kotzetang. It lies 8 metres below the level of Quartz Layer *Ac*, and some 4 metres above the Lower Cultural Zone C, Plate 9.

Cultural Zone C.—The Lower Cultural Zone C (Quartz Horizon 2 of Pei) has exactly the same lithological characters as the Upper Zone A—grey, yellow, red, and black banded sandy clay—but where exposed is only two metres thick on the average. It corresponds possibly with a rather thin ashy layer (yellow, red, and black sandy clay), containing foreign rock pebbles, clearly to be observed in the Lower Fissure between Layers 8 and 9. The fauna collected in Zone C, in association with the ashes and stone artifacts, is abundant and characteristic.

Outside of the three Zones A, B, and C, artifacts occur irregularly scattered in the mass of the brecciated sediments. It would seem, nevertheless, that the number of individuals engaged in the lithic industry, as represented by quantity and frequency of occurrence of these artifacts, had probably been increasing gradually in the course of time. A characteristic abundance of *Hyæna* and *Ursus* remains, pointing to a reduced occupation of the cave by man, is noticeable in the lowest parts of the formation that have yet been reached; while, on the other hand, the big cultural Zone A extends to no great distance from the presumably upper terminal surface of the deposit.

Usage of Fire.

Traces of artificial fire, in the Locality 1 deposit, are so clear and abundant that they require only to be mentioned without any further demonstration. In addition to the evidently burnt condition of so many bones, antlers, horn cores, and pieces of wood found in the cultural layers, a direct and careful chemical test of several specimens has established the presence of free carbon in the blackened fossils and earth (Black, 1931, *c*). The vivid yellow and red hue of the banded clays constantly associated with the black layers is also due to heating or baking of the cave's sediments.

Lithic Artifacts.

Within the past year a vast amount of additional lithic artifact material has been accumulated and on this account it has been possible to arrive at a much clearer comprehension of the industry. In the recently published 'Memoir of the Geological Survey of China' (Black and others, 1933), though the general classification of lithic artifacts there used differs but slightly from that used in the original description of Teilhard and Pei (1931), the true significance of some of the most puzzling forms has been clearly recognized and described. It would now appear that while retaining the original terminology of these authors, it is desirable to readjust somewhat the general scheme of classification previously used to describe the lithic artifacts from the Choukoutien deposit, in order to emphasize what my colleague Père Teilhard de Chardin and I both feel to be the true developmental relationships of these artificially broken and crudely worked forms. This has accordingly been done in the adjoining table.

Classification of artifacts from the *Sinanthropus* cave deposit (Choukoutien Locality 1).

Terminology.	Material.
I.—Flaked Boulders— A. Squared blocks and truncated boulders. B. Choppers. (Typologically—crude, large-sized "scrapers.") (*a*) Crude choppers. (*b*) Choppers with prepared "heel." (*c*) Choppers with edge possibly prepared.	(Derived from stream bed boulders). (1) Mostly of moderately hard, easily weathered green sandstone (Jurassic sediment). (2) A few of vein quartz—Quartz derived from pegmatite veins of adjacent granitic massif, or from intrusive seams in the Carboniferous series, exceptionally, from veins intrusive in the Ordovician limestone itself where latter approaches contact with Carboniferous (*e.g.*, east of Locality 8). (3) Exceptionally of quartzite, probably from boulders of Carboniferous conglomerates, or of quartz porphyric rocks. (4) Very exceptionally of a coarse chert probably from Jurassic conglomerates.
II.—Cores— A. Discoidal and conical vein quartz cores. B. Flakes and chips of vein quartz. C. Limestone artifacts.	A and B derived as noted above. C.—From Sinian or Ordovician partly metamorphosed limestone.
III.—Simple Scrapers or Scratchers— (Typologically—refined, small-sized "choppers.") A. Elongated or linear forms. B. Discoidal or rectangular forms.	Artifacts of Groups III and IV are fashioned :— (1) Mostly from vein quartz. (2) Also of unrolled quartz crystals, evidently purposefully collected from the granitic massif. (3) A few are from quartzite. (4) Exceptionally from a coarse chert.
IV.—Complex Scrapers or Scratchers— (Typologically distinct.) A. Pointed artifacts. B. Rostrate artifacts.	
V.—Incised and Scratched Bone.	

Reference to that table and to Plates 13 and 14 will serve to illustrate this point more clearly. To the Core Group II belong the limestone artifacts which at first sight are so puzzlingly of a rather advanced Mousterian type. These are indeed artifacts, but they certainly are not implements nor in view of their composition could they ever have been utilized as such.

A clear recognition of the typologically distinct Group IV of Complex Scrapers has emerged. Groups I and III are typologically similar, differing from one another only in points of size and refinement which are not true type differences. Among the Complex Scrapers of Group IV it has become increasingly evident that the great majority of those which are asymmetrically formed are so shaped as to be more readily adapted for use in the right hand.

Incised and Scratched Bone.

In the cultural levels of the *Sinanthropus* deposit not a few bones (PEI, 1932) are to be found upon which traces of some human workmanship are clearly impressed: scratched and incised bones (Plate 15). There also occur throughout the deposit vast numbers of burnt and fragmented bones. There can remain no reasonable doubt that the incisions and scratches in the specimens illustrated have been produced by human agency. Such evidence of artificial workmanship does not, however, bring these fragments within the category of implements nor can we yet offer indisputable evidence of the existence of a true bone industry in Choukoutien times. Professor BREUIL's (1931) brilliant and attractive hypothesis remains to be tested. A special study of some ancient fossiliferous site in which the possibility of human influence may be excluded must first be made in order to determine how naturally broken bones may be classified. Further, in the case of the Choukoutien deposit itself, it will also be necessary to make an especially careful collection of bones from the cultural layers now defined in order to exclude the possibility of all secondary breakage or chipping of specimens, a restriction which was not observed during the collection and preparation of the material available up to the present. Until these conditions have been fully met, it would appear that the question whether or not a true bone industry existed in Choukoutien must remain an open one.

GENERAL CONCLUSIONS AND SUMMARY.

It is now necessary briefly to summarize and tentatively to evaluate the results of the foregoing observations on the *Sinanthropus* fossil remains so far recovered, and on their environment, physical, biological, and cultural, in the Choukoutien cave deposit. Before proceeding with such a summary it is desirable to define clearly the meaning of certain descriptive terms there to be used, since the commonest cause of differences of opinion is to be found in lack of such clarity. The terms *generalized* and *specialized*, *progressive* and *conservative* are among those requiring such definition, terms such as archaic and modern being, on the other hand, quite unambiguous.

If one considers the characters of a cube, a cylinder, and a sphere, each of 1 inch diameter, then within this series the cube may reasonably be considered as the most generalized form, for theoretically from it may be turned a cylinder of 1 inch diameter and height, and from the latter again a 1 inch sphere may be fashioned ; but the process is not reversible. The cylinder may be considered as more generalized than the sphere, while the latter is the most specialized of the three solids ; also the sphere may legitimately be considered as the most progressive of the series if the evolutionary movement be in its direction.

Obviously any one of the three forms may be considered archaic if the term be applied from the evolutionary direction of a series of smaller and similar solids, an infinite number of which may be derived from parents of larger dimension. If progress be defined as in the direction of the sphere, then any deviation away from a preceding generalized type in the series will represent archaic specialization. Conservatism may be defined in such connection, as the reverse of progress, or the crystallization of intermediate type. It is in the above general sense of implication that the terms generalized, specialized, progressive, etc., are used here and have been used in the past, the direction of progress in all cases having been considered to be that leading to the modern surviving type.

(1) *Dentition.*—The molar crown cusp and groove pattern in *Sinanthropus* is of the generalized *Dryopithecus type,* the crown proportions and entoconid development being of a generalized and progressive type whose slight modification in a given direction would readily produce that dominant in modern hominids.

All specimens of third upper molar *Sinanthropus* teeth so far recovered show distinct evidences of root fusion and reduction in crown size. On the other hand, while the last lower molars in this form may show similar evidences of marked reduction, they may, on the contrary, be developed to a degree but little if any less advanced than are the second molars. Occurring in *Sinanthropus,* this evident tendency to third molar variability would seem in turn to imply its initial development at a relatively early evolutionary stage in the hominid group, and its active retention to modern times in the surviving type. In this respect, therefore, *Sinanthropus* resembles the stem stock.

In the molar teeth of *Sinanthropus* both root and corpus regions are equally well developed, the latter region being in all cases large in proportion to the relatively low crown. This condition is to be correlated with the characteristically roomy development of the molar pulp chamber, the size of the latter in *Sinanthropus* being manifestly greater than that either in modern man or anthropoids. This development of the *cavum dentis* in the molar teeth of *Sinanthropus* has been defined as *megaphanic,* in contradistinction to taurodontism, where enlargement of the *cavum dentis* takes place at the expense of the root region. The megaphanic condition observed in *Sinanthropus* molars is believed to represent a generalized early hominid character, subsequently specialized in two opposite directions to give rise to the modern and the Neanderthaloid types.

In comparison with the peculiarly specialized upper molar teeth of *Pithecanthropus*, those of *Sinanthropus* are manifestly of such generalized hominid type that their derivation from a pithecanthropine prototype cannot have occurred, though the reverse might well have happened.

(2) *Mandibulæ*.—Except for its symphyseal region, the general aspect of the lower jaw in *Sinanthropus*, both in juvenile and adult individuals, was strikingly neanthropic. The curve of the dental arcade and the form and relations of the condylar region are essentially modern in type, though to judge from the strength and shape of the horizontal ramus, the stresses due to use were evidently distributed in the jaw of *Sinanthropus* in a somewhat different manner than in modern man. The symphysis, on the other hand, of which the complete morphology is known at present only in its juvenile stage, is of a very archaic type recalling in many respects the form of this region in anthropoids. Modification of the archaic generalized form of the chin region in the direction of modern man was evidently a process quite independent of the development of a typically generalized hominid dentition. Similarly, the presence of multiple mental foramina in the *Sinanthropus* jaw is to be interpreted as the retention in that form of an archaic generalized feature common both to hominids and anthropoids.

(3) *Skull*.—Among the skull elements the temporal bones are of special interest since they display, side by side, evidences both of a progressive evolution in the direction of the modern type (glenoid area), and of a beautifully generalized hominid morphology (tympanic element). In the former as in the condylar region of the jaw an essentially modern morphology obtained. On the other hand, the tympanic region of *Sinanthropus* has retained a morphology so generalized that its close similarity to that of the hominid stem form is hardly to be doubted.

The adolescent Locus E and the adult Locus D *Sinanthropus* skulls are of similar type, differing from one another only in minor points of ontogenetic age and probably also in sex. The skull of *Sinanthropus* represents a hominid type which differs essentially, on the one hand, from that of modern Neanderthal or Rhodesian man, and, on the other, from that of anthropoids.

Obvious resemblances are to be observed between the skull of *Sinanthropus* and *Pithecanthropus*. Craniographic and craniometric comparisons, however, make it evident that in many very significant skull features the two forms differ widely from one another, the skull of *Sinanthropus* being that of a very generalized but quite progressive type, while that of *Pithecanthropus* is both specialized and conservative.

(4) *Endocranial cast*.—A study of the endocranial cast of *Sinanthropus* has made it clear that the brain of this form was in all essentials a typically human one. It is further probable that *Sinanthropus* was right handed and had evolved the nervous mechanism for the elaboration of articulate speech.

(5) *Upper extremity*.—Even from the meagre evidence at present at our disposal it may definitely be stated that in the morphology of his upper extremity *Sinanthropus* differed in no important respect from modern man.

(6) *Lower extremity.*—No specimens unquestionably referable to the lower extremity of *Sinanthropus* have yet been discovered. Four anomalous terminal phalanges of curiously suggestive morphology have been recovered from Locality 1 and it is possible that one or more of these may represent toe bones of *Sinanthropus*. The true status of these *ossa incerta* cannot yet be determined.

(7) *Geological and palæontological environment.*—The Choukoutien fossiliferous deposits represent a perfectly distinct physiographic cycle and faunistic stage, older than the Upper Pleistocene (Loess) and younger than the Late Pliocene (Sanmenian).

The *Sinanthropus* deposit itself (Locality 1) clearly represents the remnants of a great and ancient cave which had been slowly and completely filled by an underground sedimentation in the course of a protracted occupation by both wild animals and man. This complex of brecciated limestone and fossiliferous occupational detritus was subsequently cemented to form a hard brecciated travertine, the latter with the fissured limestone of the hill itself becoming as a single mass eventually worn and rounded to its present form by subsequent erosion. A whole superstructure of dissected limestone now no longer present must have existed in the past during the period in which *Sinanthropus* occupied the site.

At that period some faunistic interchange with the South certainly occurred, as indicated, for instance, by the arrival in North China of *Bubalus*. The occurrence of *Macacus* at Choukoutien can, however, have but little, if any, significance in this connection since that form is a catarrhine of typically Holarctic distribution. The situation provides also no sound argument for a southern derivation of the progressive northern hominid *Sinanthropus* from his contemporary southern relative *Pithecanthropus*, since the latter was provided with a dentition much too highly specialized to have been ancestral to that of *Sinanthropus* (*vide supra*). However, the presence of *Bubalus* in North China indicates that at this time a way towards the South may have been open to *Sinanthropus*, though curiously enough a generally effective faunal barrier seems to have existed then, just as now, between the Yangtze and Hoangho basins.

Judging from the animal and plant remains, the climate was milder in Choukoutien times than now, the persistence of a red staining of the loams (probably not wholly to be accounted for by a re-washing of earlier sediments) points to the prevalence of conditions at present characterizing somewhat lower latitudes (Black, 1931, *b*).

(8) *Cultural environment.*—In a very broad sense the Choukoutien culture may be defined as an industry of old palæolithic type showing some superficial Mousterian analogies. Three major types of lithic artifacts may be recognized: "Choppers and Scrapers," "Cores," and "Complex Scrapers," and it is a noticeable fact that where implements of the "Chopper" or "Scraper" variety happen to be asymmetrical, the majority of such are so shaped as to be conveniently adapted for use in the right hand. On account of the almost complete absence of flinty material, the real stage reached by the Choukoutien culture is difficult to evaluate.

It would seem highly improbable that there can be any direct evolutionary relationship between the well-recognized sequence of Western European palæolithic cultures and that of Choukoutien. Some evidence has indeed been adduced from a comparison of the workmanship of the lithic artifacts from the Choukoutien Cultural Zones A and C indicating possibly some advance in technique during the period separating the two (BLACK and others, 1933). This, however, is largely to be attributed to a choice of better materials in the later stages of the culture, and there is yet no evidence indicating that, at any time during the evolution of the latter, the artisan was truly a master of his material (TEILHARD and PEI, 1931). It would therefore seem highly probable that the original founders of the Choukoutien hominid community reached that region unburdened by any cultural tradition in the art of working stone. Thus, though these pioneers probably arrived with a knowledge that crude stones could be used in a variety of useful ways, there appears to be sound basis for the belief that the lithic industry of Choukoutien was largely, if not wholly, a slow autochthonous development.

That the development in any case was indeed an extraordinarily slow one is confirmed by the relatively insignificant advances made in technique over the many, many centuries during which the *Sinanthropus* community must have occupied the great cave of Choukoutien. Through a much lesser thickness of deposit (only some 20 metres) the cultural layers of the famous Castillo cave near Santander in Northern Spain range from a very low Mousterian to the Azilian. The 12 metres thick cultural deposits of the Observatoire Cave in Monaco cover the time between very old Palæolithic and Aurignacian cultures. Judged by the thickness of the occupational layers of the Choukoutien cave deposit, the essential cultural characters of the *Sinanthropus* community suffered no change during a period at least three times as long as that required by the Castillo cave dwellers for cultural evolution from low Mousterian to Azilian.

The truly human status of *Sinanthropus* has thus been demonstrated beyond any possibility of doubt. A further point, however, deserves notice, in view of the confusion which seems to have arisen about the use and implication of the words *human*, *man*, and *hominid*. The former term cannot correctly be used as a synonym of *Homo* or interchangeably with the latter word any more than it would be correct to use the terms anthropoid and *Gorilla* as synonymous. A gorilla is an anthropoid, but so also is an orang or chimpanzee. In like manner *Homo* is of human status, is a true man and dominant hominid, *i.e.*, belonging to the man family Hominidæ ; but *Homo* as we know is by no means the only genus included within the latter, all of whom are *hominid* and *human* and may also with perfect propriety be referred to as man.

The question has indeed been raised by Professor M. BOULE as to whether or not *Sinanthropus* was of truly human status and thus capable of being the maker of the crude stone artifacts found in association with his skeletal remains. The obvious answer is that *Sinanthropus* was without doubt of truly human status, a hominid representative of but one of the genera or kinds belonging to the family Hominidæ, mankind, fully capable in view of his mental and physical organization of being the sole artificer of the cultural debris associated with his skeletal remains.

Finally there remains to be noted the generic status of *Sinanthropus*. The latter was conferred upon that hominid upon the basis of definite and distinctive morphological characters which probably would have received but little if any criticism had a form other than hominid been involved. The generic name *Sinanthropus* was created to be a useful tool. The names *Palæoanthropus*, *Eoanthropus*, *Pithecanthropus*, and *Sinanthropus* are at once useful and distinctive, the last one particularly so since its derivation is so obviously zoogeographic, carrying with it no implication of preconceived relationship. Ideas regarding the latter must necessarily change from time to time as new evidence becomes available. When, therefore, definite morphological facts permit, it would seem desirable to accord generic status of zoogeographical significance to a new discovery of truly ancient hominid remains, and thus to avoid at the outset prejudicing or rendering obscure the ultimate issue of their precise relationship within the hominid group.

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DESCRIPTION OF PLATES.

PLATE 6.

Upper photograph.—General view of the Choukoutien Locality 1 taken from across the valley to the north in April, 1932 (*cf.* fig. 3). Upon the old quarry terrace to the right (west) in the photograph the buildings of the Cenozoic Research Laboratory's Choukoutien headquarters are to be observed, while farther to its left another small building is situated, above the terrace at the base of the hill in which occurs the deposit itself and a few metres to the west of the western end of the latter. This building is the little temple shrine of Shenshanmiao and is one of the most useful topographical landmarks of the Locality. The cross-like cutting of the Main Deposit leading downwards into the Lower Fissure region is very evident in this view. Towards the eastern end of the hill slope the two openings into the Kotzetang cave are to be seen just above the terrace. Upon the slope above the latter cave mouth lay a thick coating of old, firmly cemented, white lime waste, and a systematic removal of the latter to expose the original hill slope was under way when the photograph was taken.

Lower photograph.—Panoramic view of the isolated Choukoutien foot-hill in the eastern part of which occurs the *Sinanthropus* cave deposit; taken in April, 1932. At the extreme right of the photograph is to be seen the western extremity of this low rounded double-summited hill, this boundary being marked by a dark pillar of fissure deposit exposed in an old quarry. The latter deposit is our Locality 2. The hill is seen to be divided into eastern and western halves by a shallow valley, and it is worthy of note here that the summits of both parts are capped by thick layers of stalagmitic deposit in which is preserved abundant remains of *Chiroptera*, and of a mammalian fauna of Lower Pleistocene age (fig. 30; BLACK and others, 1933, pp. 14, *et seq.*). A whole superstructure of limestone, honey-combed with caves, must have existed at the time this region was occupied by *Sinanthropus* in order to allow of this stalagmitic deposition on what are now the highest points of the isolated foot-hill.

PLATE 7.

Wide angle photograph of Locality 1, *Sinanthropus* deposit, from the north-east taken in April, 1932. On the extreme right the Shenshanmiao shrine is to be seen and a short distance east (left) of it, the extreme western part of the Main Deposit excavation is evident. An excellent idea of the thickness of the deposit above the terrace can be gained by noting the size of the workmen on the eastern slope of the hill (*cf.* fig. 30).

PLATE 8.

Two wide angle near-views of the excavations from the north-east taken in April, 1932. The relations of the preserved portion of the limestone wall limiting the deposit on the north to the Kotzetang and Main Deposit areas are evident (*cf.* fig. 29). In the upper figure the massive blocks of brecciated limestone earlier referred to as "Collapsed roof" (TEILHARD and YOUNG, 1930) in the eastern part of Layer 3 of the Main Deposit are clearly to be observed (*cf.* fig. 30).

PLATE 9.

Wide angle photograph of the south face of the trench cut in the floor of Kotzetang cave in 1931. The original floor level of the Kotzetang is to be seen in the shadow at the top of the photograph and the scale may be gauged by the rod which is about 3 metres in length. The dark layers at the bottom of the photograph are the red, yellow, and black coloured laminæ of Cultural Zone C (Quartz Horizon 2 of PEI, 1931, *c*), and on a level with the rod the irregularly compressed laminæ of Cultural Zone B are to be recognized (*cf.* fig. 30).

PLATE 10.

The six normæ of the adolescent *Sinanthropus* Locus E skull.

PLATE 11.

The six normæ of the adolescent *Sinanthropus* Locus D skull.

PLATE 12.

FIGS. 1A, 1B, 1C, and 1D, respectively, views of the superior, anterior, inferior, and posterior surfaces of the left clavicle fragment of *Sinanthropus*, nat. size. Figs. 2A, 2B, 2C, 2D, 2E, and 2F, respectively, views of the proximal, distal, dorsal, ventral, radial, and ulnar surfaces of the left os lunatum of *Sinanthropus*, nat. size: orientation: in *a*, *b*, *e*, and *f* the dorsal non-articular surface is towards the top of the page; in *c* and *d* the radial (navicular) surface is to the right; nat. size. Figs. I, II, III, and IV show in the upper row dorsal, and in the lower plantar views of the four *ossa incerta*, nat. size.

Plate 13.

Fig. 1.—Lithic artifact of Chopper type in greenstone from Cultural Zone C, the edge flaked by use is towards the top of the page, while the base or heel has been artificially prepared ; × 3/4 nat. size. Fig. 2.—Lithic artifact of Chopper type in greenstone from Cultural Zone C showing evidences of a more or less prepared edge (left) while the heel is naturally rounded ; × 3/4 nat. size. Fig. 3.—Lithic artifact of Chopper type in greenstone from Cultural Zone B with a prepared heel towards the bottom of the page and an upper edge flaked by use ; × 3/4 nat. size.

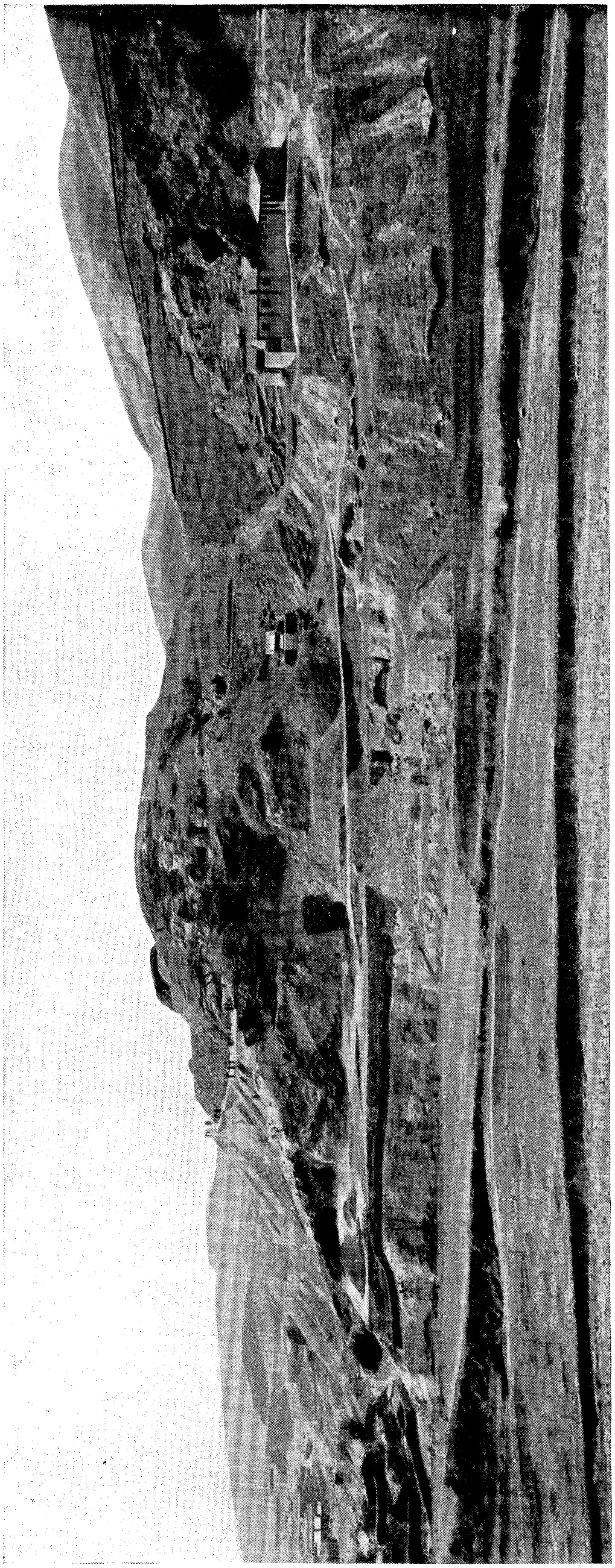
Plate 14.

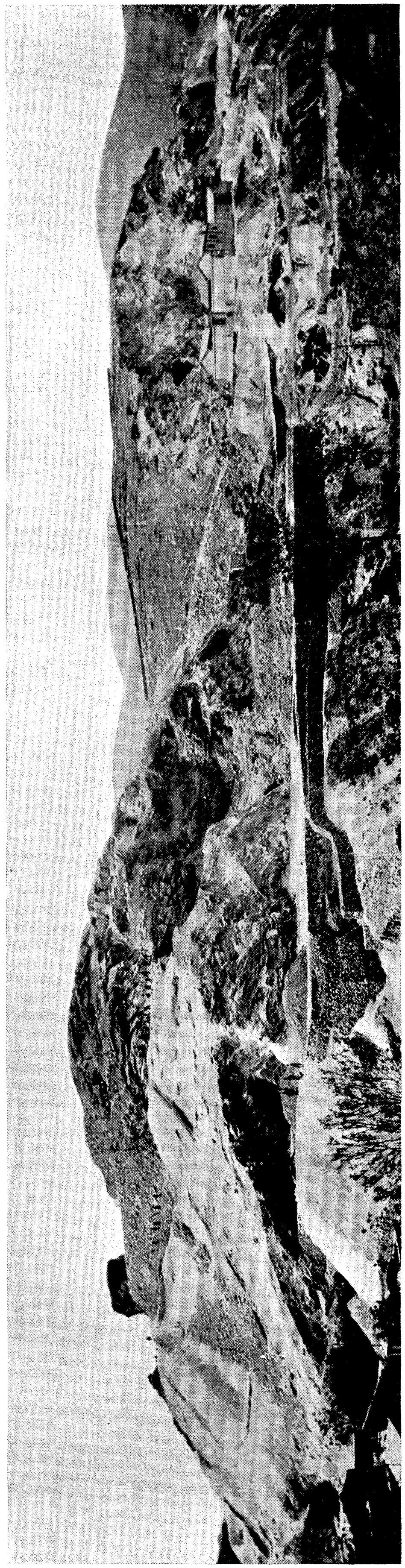
(Upper). Three lithic artifacts of the Core type from Cultural Zone C, all at × 3/4 nat. size. Figs. 1A and 1B, respectively, views of the upper and lower surface of an artifact in partly metamorphosed limestone, on the lower surface of which are to be observed the white bruise marks left as the result of many blows, the marks of those which produced the characteristically broken upper surface all being beautifully preserved. Figs. 2A and 2B, respectively, views of the upper and lower surface of another artifact in partly metamorphosed limestone, in which the superficial likeness to some implement of Mousterian type is particularly obvious, but on which likewise the marks are preserved of the blows which served to produce its implement-like facies as well as those which did not result in such fracture. Figs. 3A and 3B, respectively, views of the upper and lower surface of a conical core in vein quartz on the lower surface of which numerous bruise marks are to be observed among which are evident the traces of those which produced the characteristically worked or fractured upper surface.

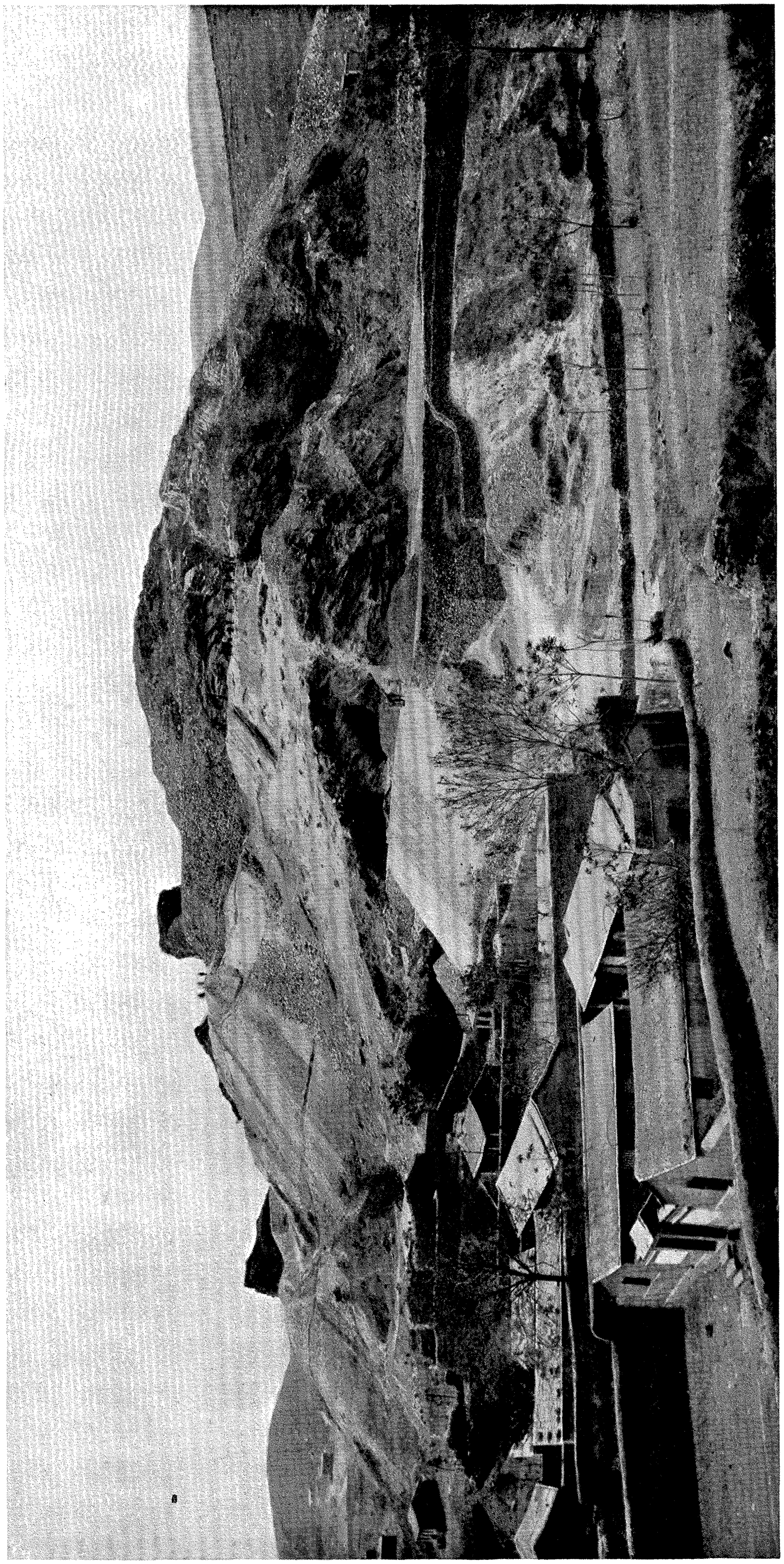
(Lower). Photographs of six quartz artifacts of the Complex Scraper or Scratcher type, all from Cultural Zone C, all nat. size. Rostrate types are illustrated in figs. 1 and 2, the former being of vein quartz, the latter of beautifully clear quartz crystal. In each the characteristic " beak " is to be seen, and such an implement may reasonably be referred to as having been used by a right-handed individual. Figs. 3, 4, 5, and 6 represent artifacts of the Pointed type, though that shown in fig. 5 approaches to the Rostrate form. With the exception of the artifact shown in fig. 4, the remaining three forms are each evidently asymmetrical to a degree adapting them best for use by the right hand. The artifacts shown in figs. 4, 5, and 6 are of vein quartz, that in fig. 3 being of quartz crystal, the natural surfaces of the latter being clearly evident in the lower part of the photograph. It is to be noted that the bases in artifacts of this type are entirely crude and unprepared in any way.

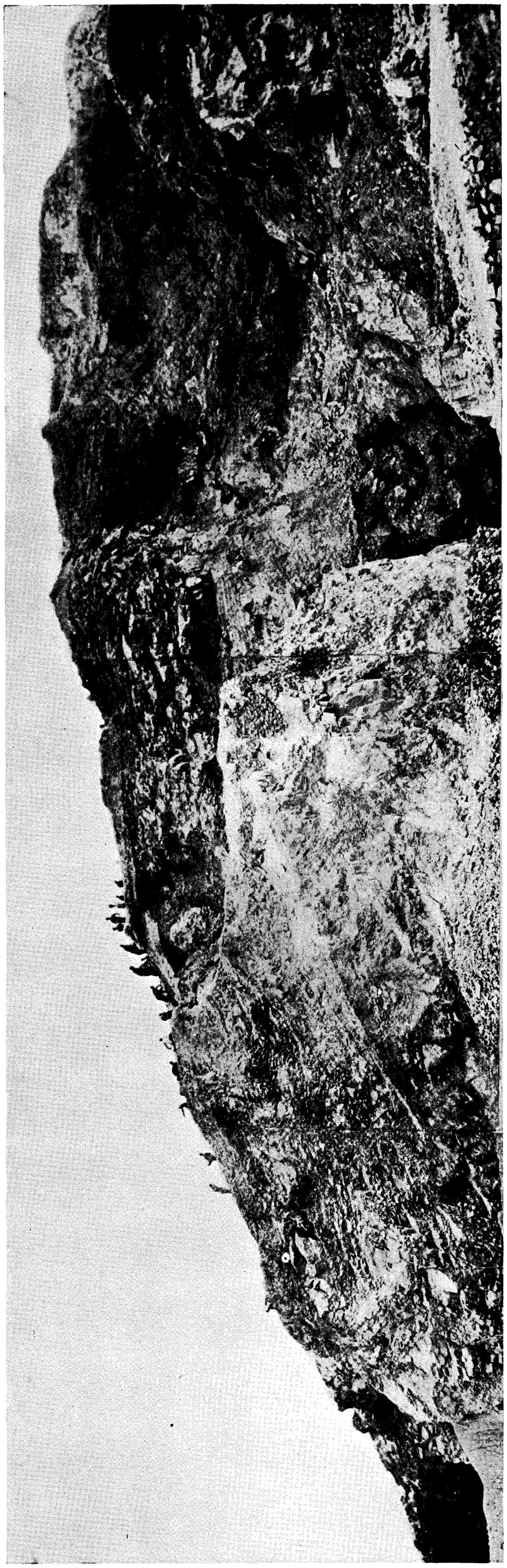
Plate 15.

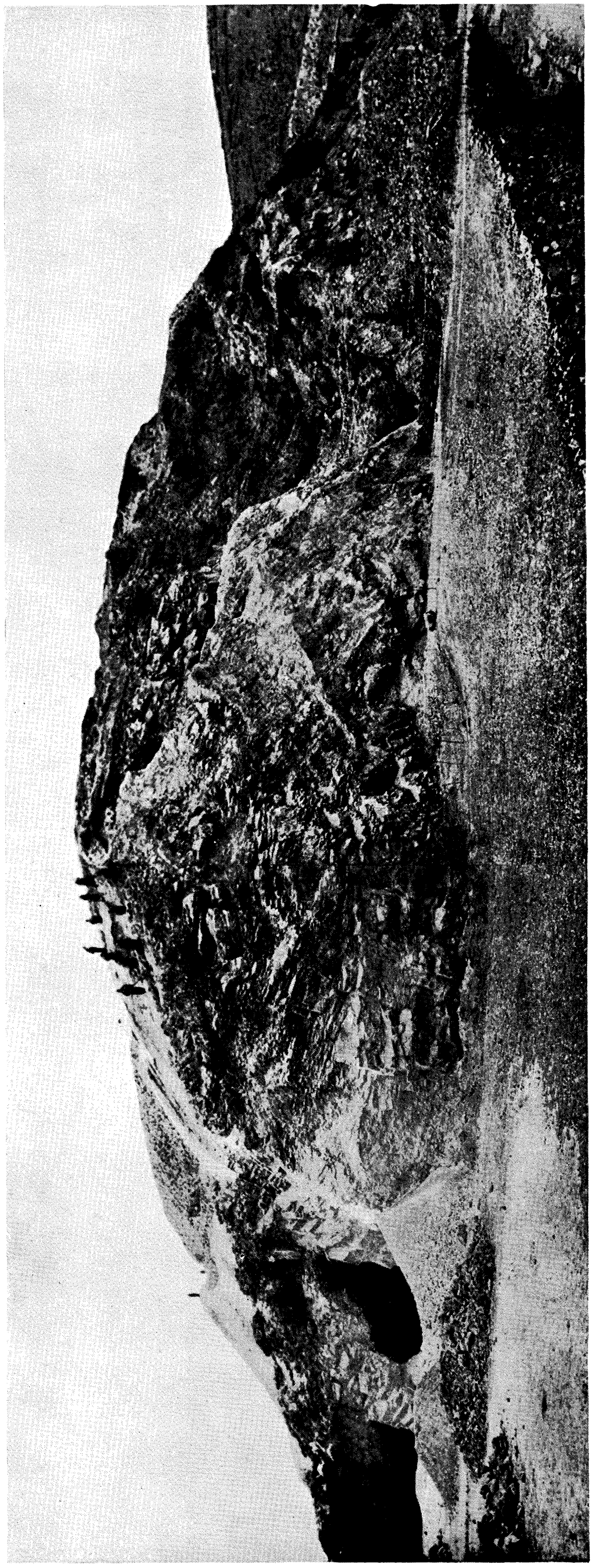
Photograph, illustrating a number of specimens of incised and scratched bones from Cultural Zone C (Pei, 1932), all at natural size. In figs. 1 and 5 the marks of angular incisions are clearly evident ; in fig. 2 three irregularly curved incisions are evident ; in fig. 3 two and in fig. 4 three parallel and straight incisions are to be seen. In fig. 6 the incision has evidently been produced at a single stroke by some hard irregularly pointed implement (Black and others, 1933, fig. 81).

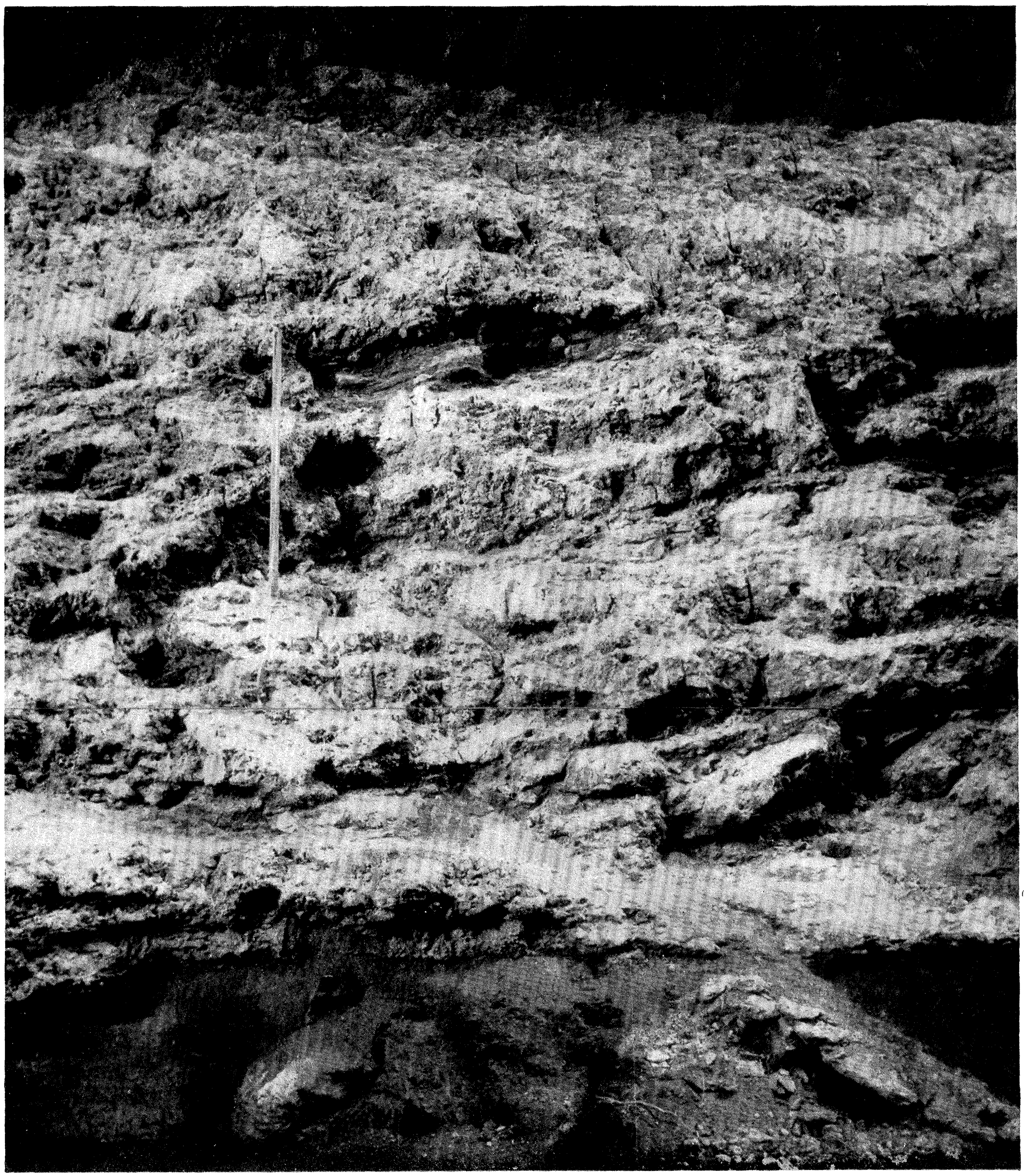


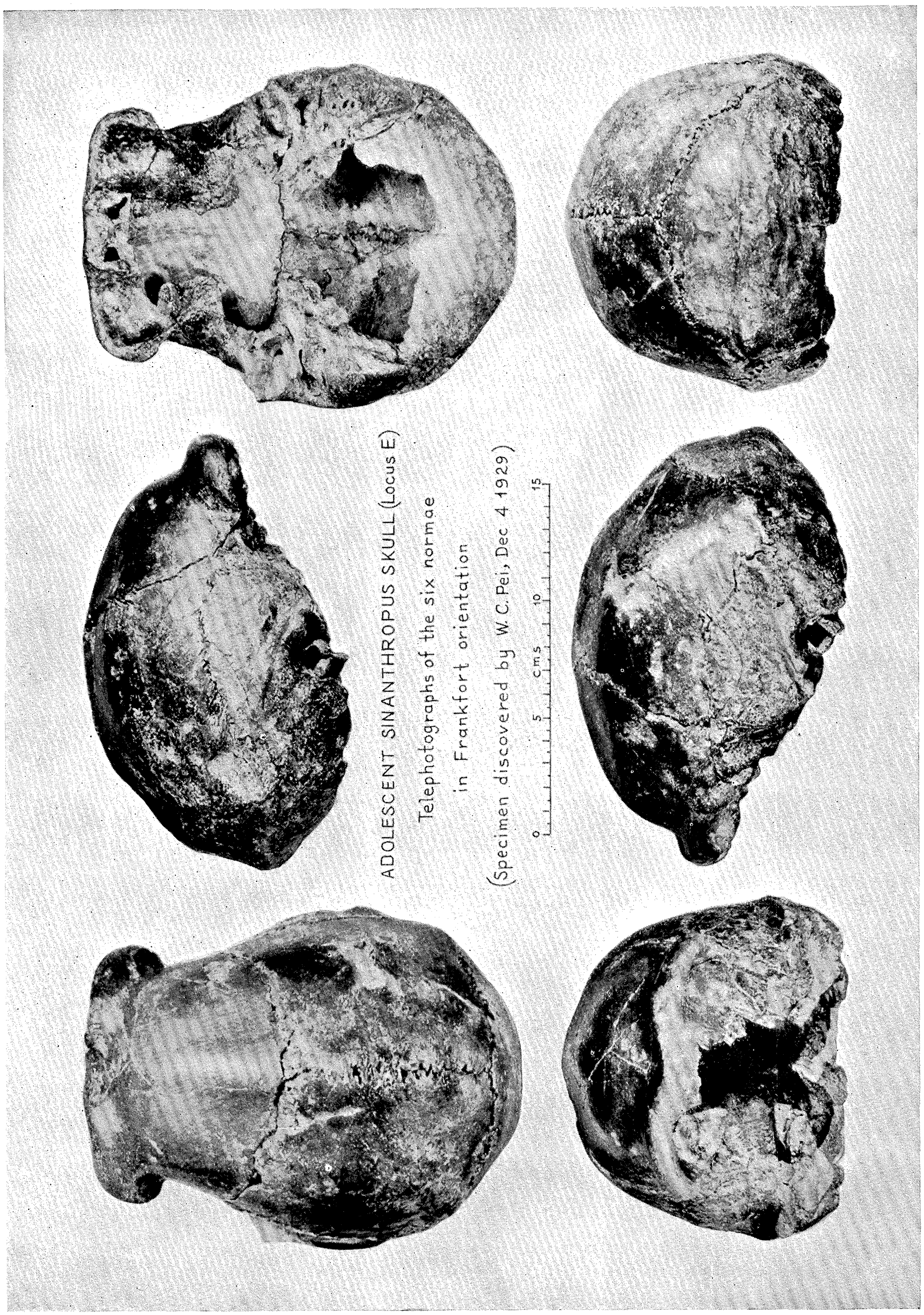








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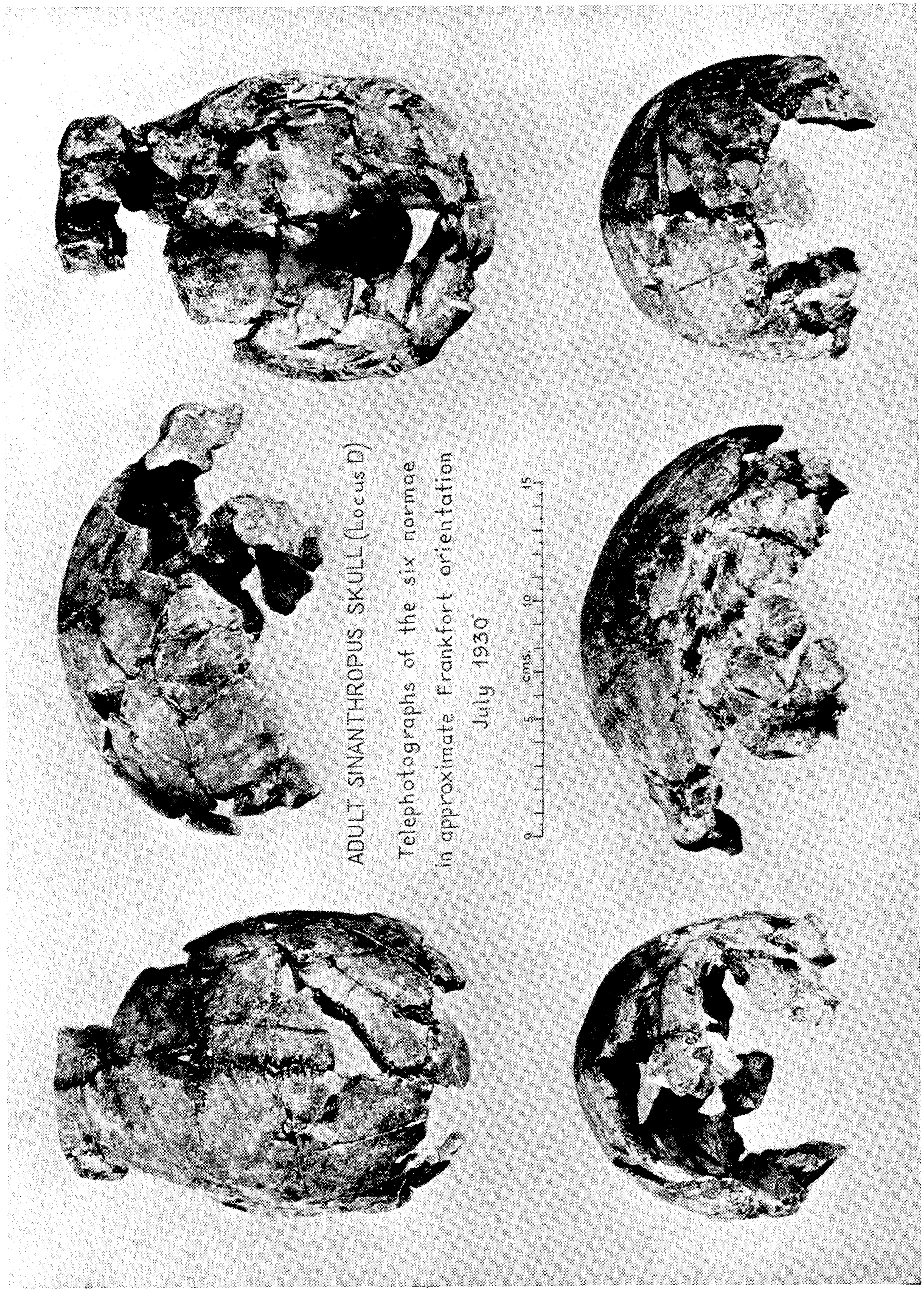
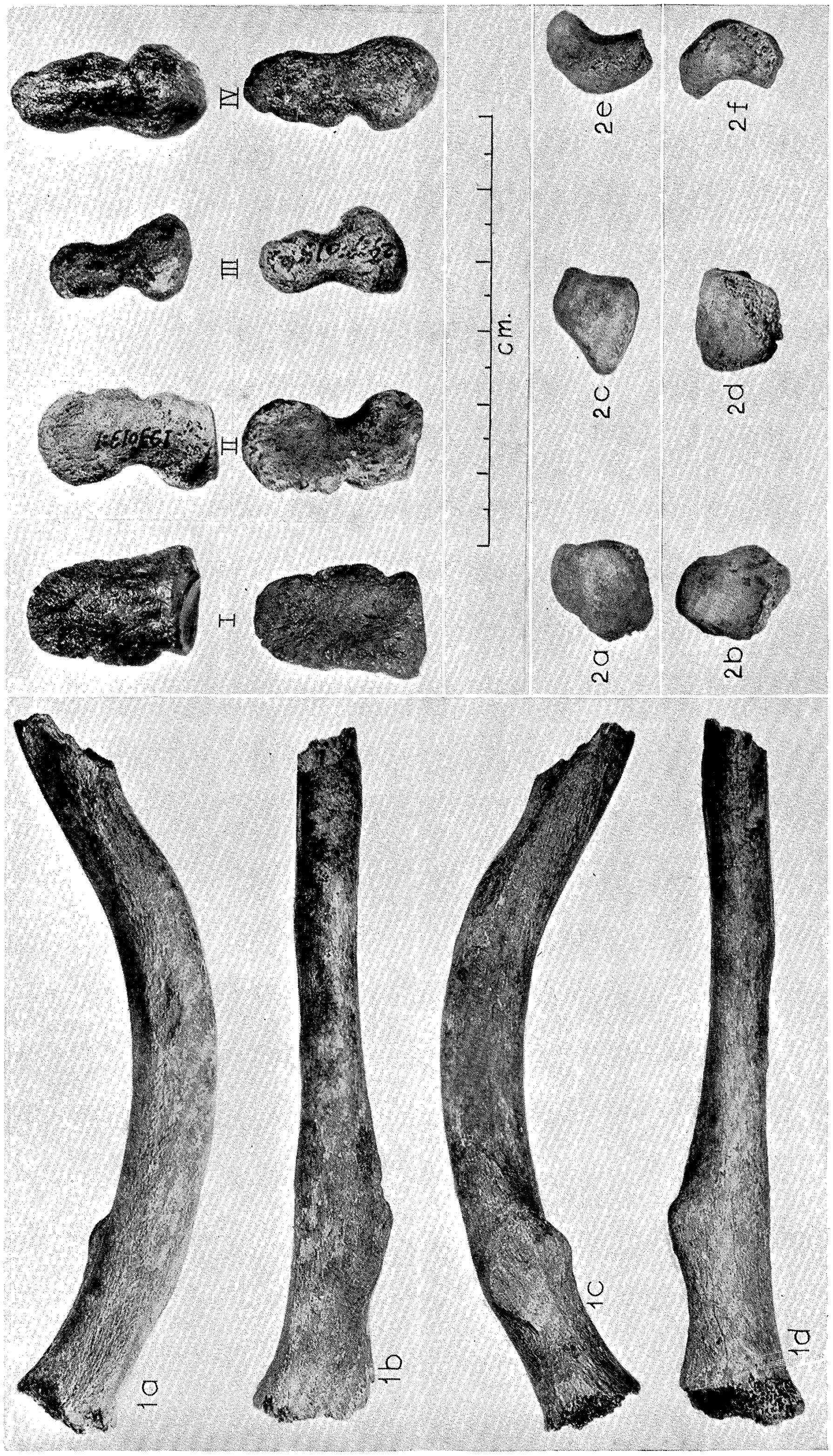
Telephotographs of the six normae
in Frankfort orientation
(Specimen discovered by W. C. Pei, Dec 4 1929)
0 5 cms 10 15


ADULT SINANTHROPUS SKULL (Locus D)
Telephotographs of the six normae
in approximate Frankfort orientation
July 1930
0 5 cms. 10 15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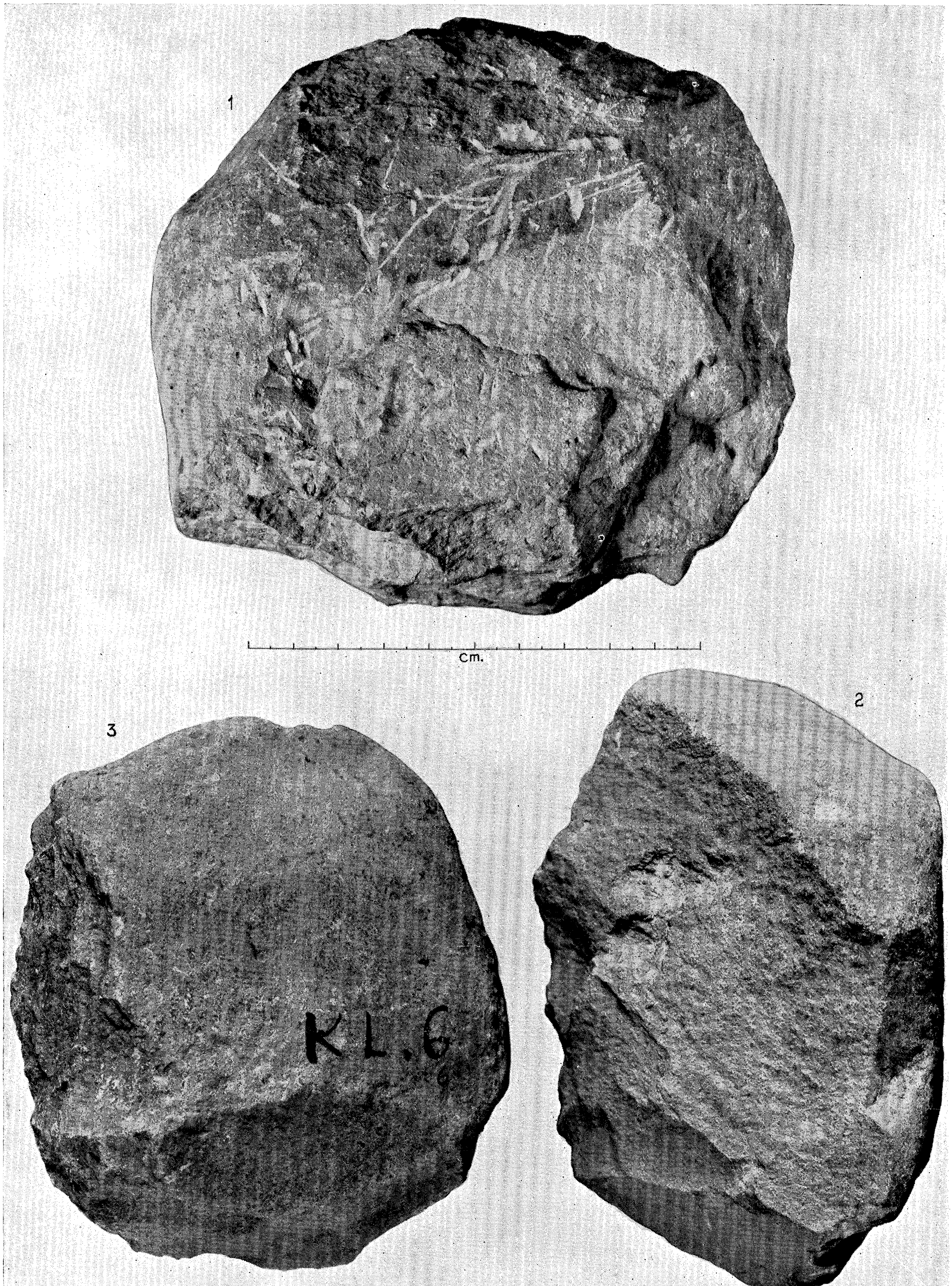
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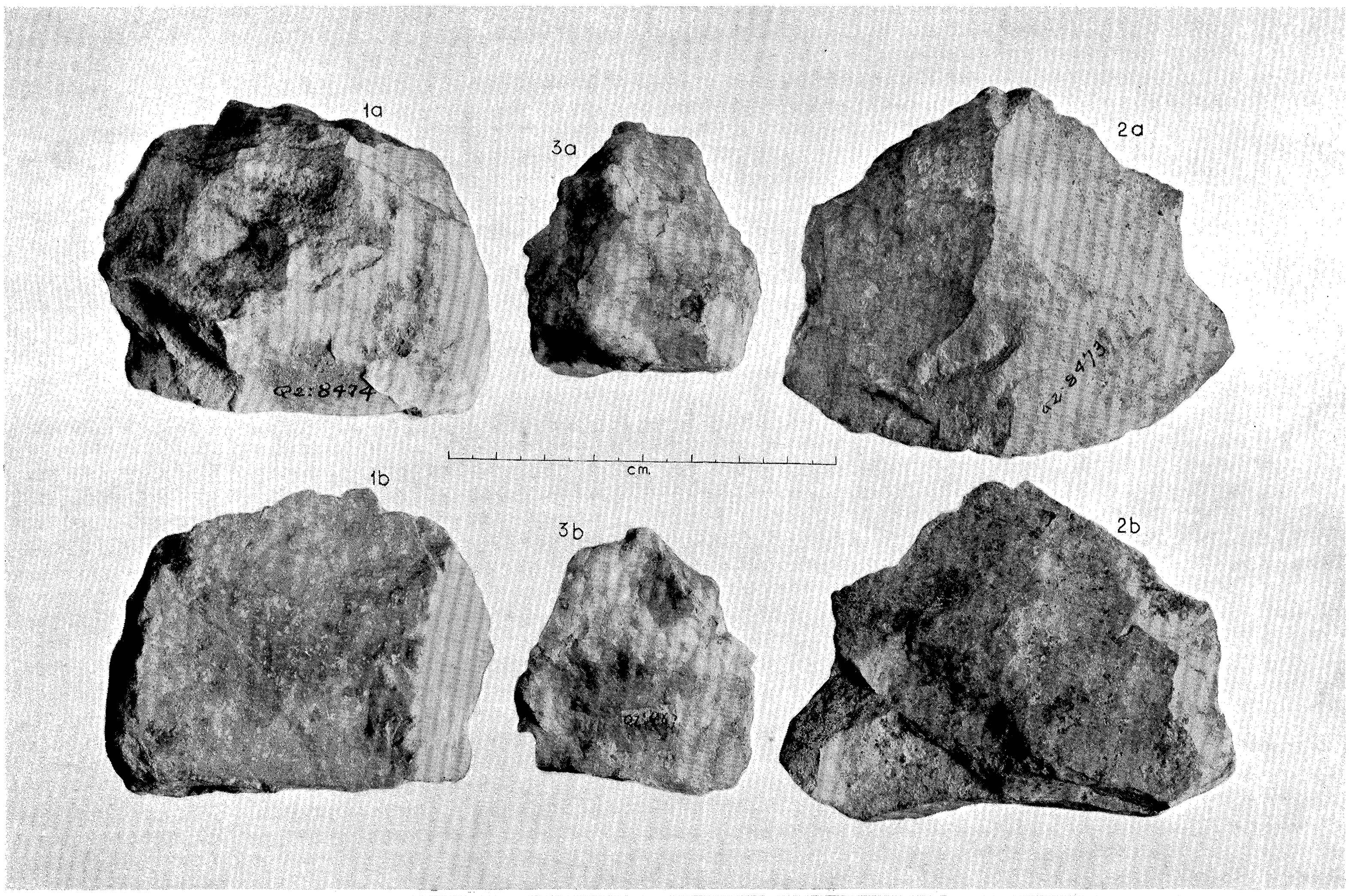
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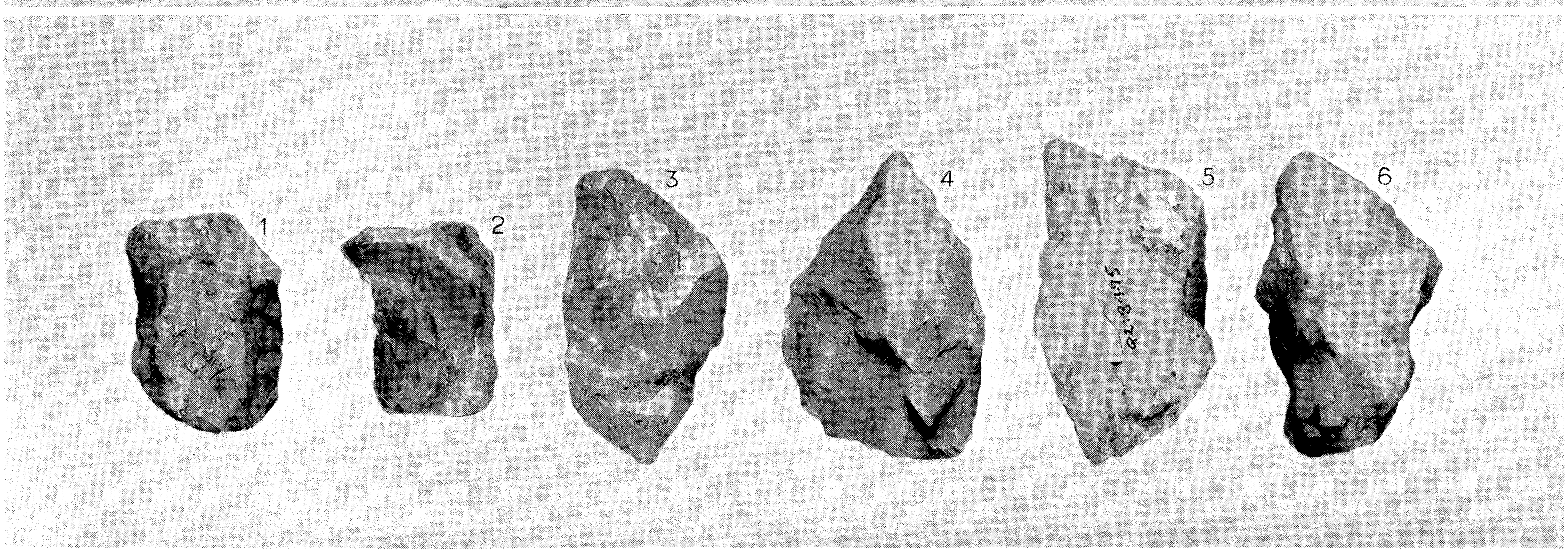
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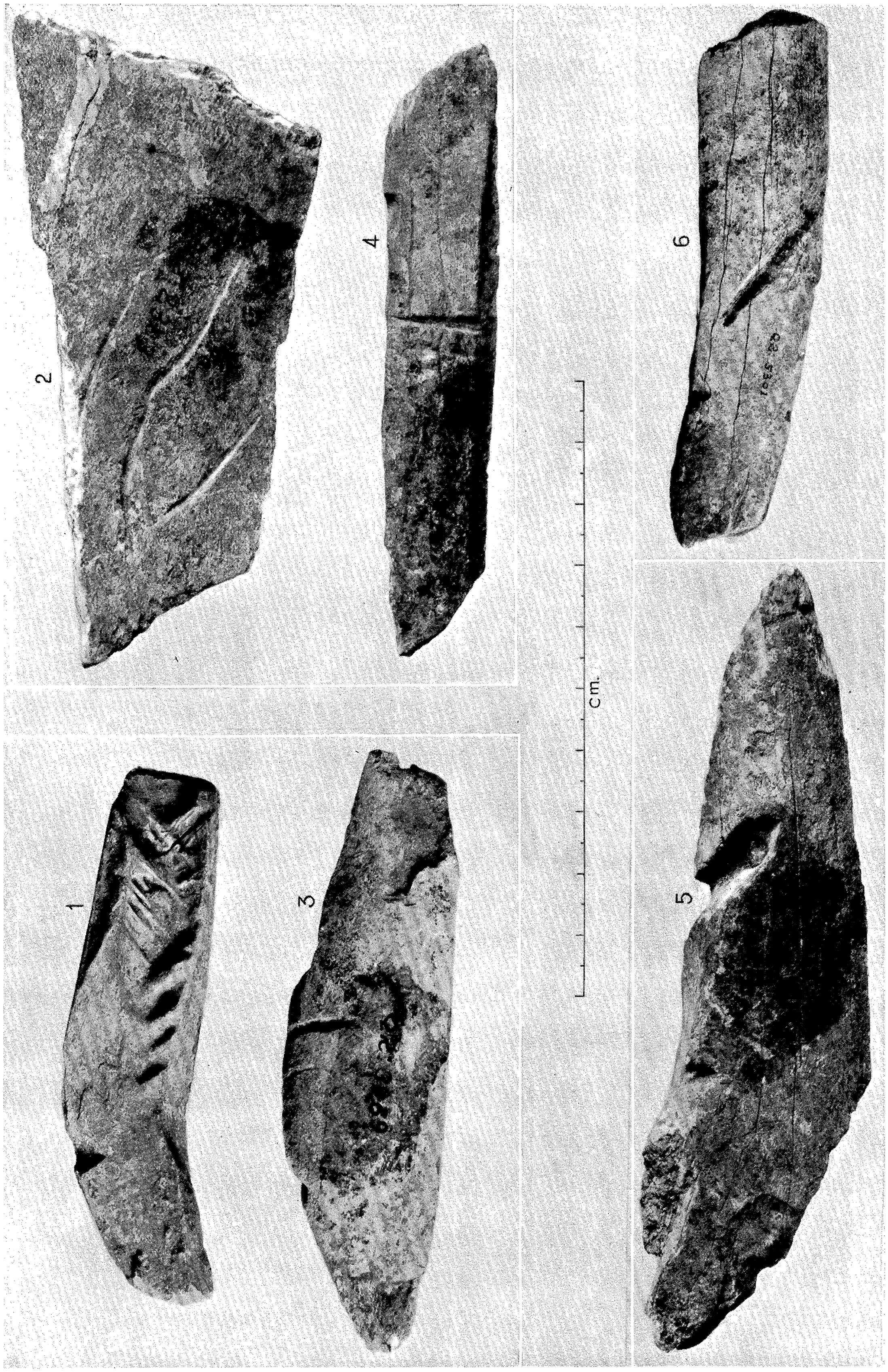
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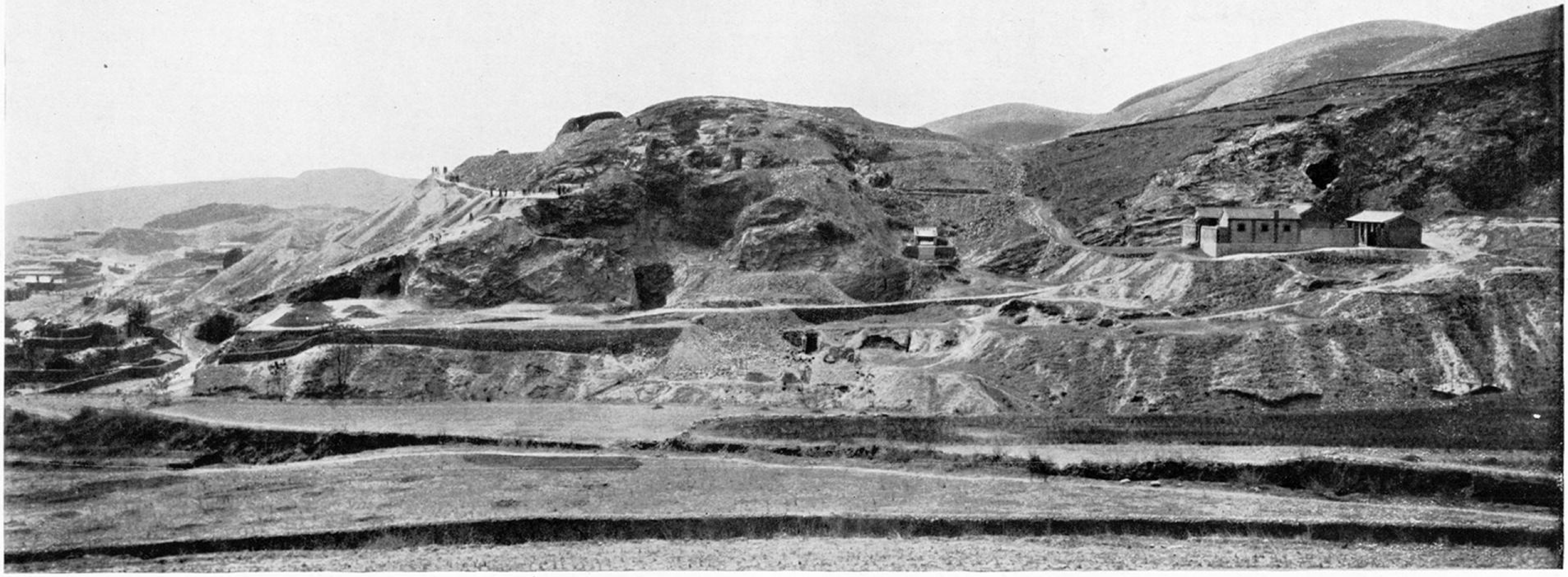

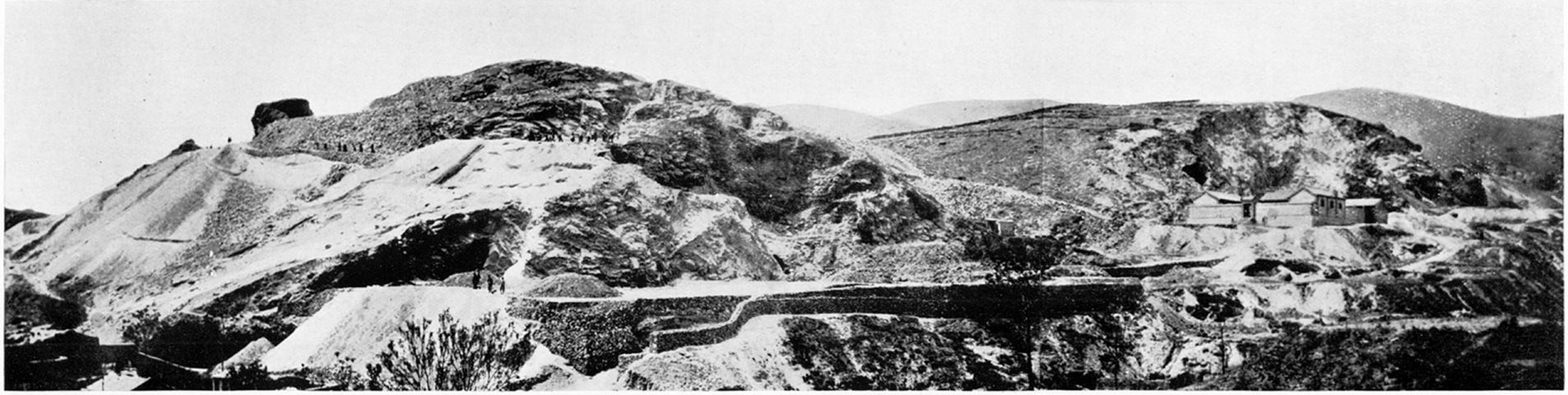

PLATE 6.

Upper photograph.—General view of the Choukoutien Locality 1 taken from across the valley to the north in April, 1932 (*cf.* fig. 3). Upon the old quarry terrace to the right (west) in the photograph the buildings of the Cenozoic Research Laboratory's Choukoutien headquarters are to be observed, while farther to its left another small building is situated, above the terrace at the base of the hill in which occurs the deposit itself and a few metres to the west of the western end of the latter. This building is the little temple shrine of Shenshanmiao and is one of the most useful topographical landmarks of the Locality. The cross-like cutting of the Main Deposit leading downwards into the Lower Fissure region is very evident in this view. Towards the eastern end of the hill slope the two openings into the Kotzetang cave are to be seen just above the terrace. Upon the slope above the latter cave mouth lay a thick coating of old, firmly cemented, white lime waste, and a systematic removal of the latter to expose the original hill slope was under way when the photograph was taken.

Lower photograph.—Panoramic view of the isolated Choukoutien foot-hill in the eastern part of which occurs the *Sinanthropus* cave deposit; taken in April, 1932. At the extreme right of the photograph is to be seen the western extremity of this low rounded double-summited hill, this boundary being marked by a dark pillar of fissure deposit exposed in an old quarry. The latter deposit is our Locality 2. The hill is seen to be divided into eastern and western halves by a shallow valley, and it is worthy of note here that the summits of both parts are capped by thick layers of stalagmitic deposit in which is preserved abundant remains of *Chiroptera*, and of a mammalian fauna of Lower Pleistocene age (fig. 30; BLACK and others, 1933, pp. 14, *et seq.*). A whole superstructure of limestone, honey-combed with caves, must have existed at the time this region was occupied by *Sinanthropus* in order to allow of this stalagmitic deposition on what are now the highest points of the isolated foot-hill.

Plate 7.

Wide angle photograph of Locality 1, *Sinanthropus* deposit, from the north-east taken in April, 1932. On the extreme right the Shenshanmiao shrine is to be seen and a short distance east (left) of it, the extreme western part of the Main Deposit excavation is evident. An excellent idea of the thickness of the deposit above the terrace can be gained by noting the size of the workmen on the eastern slope of the hill (*cf.* fig. 30).

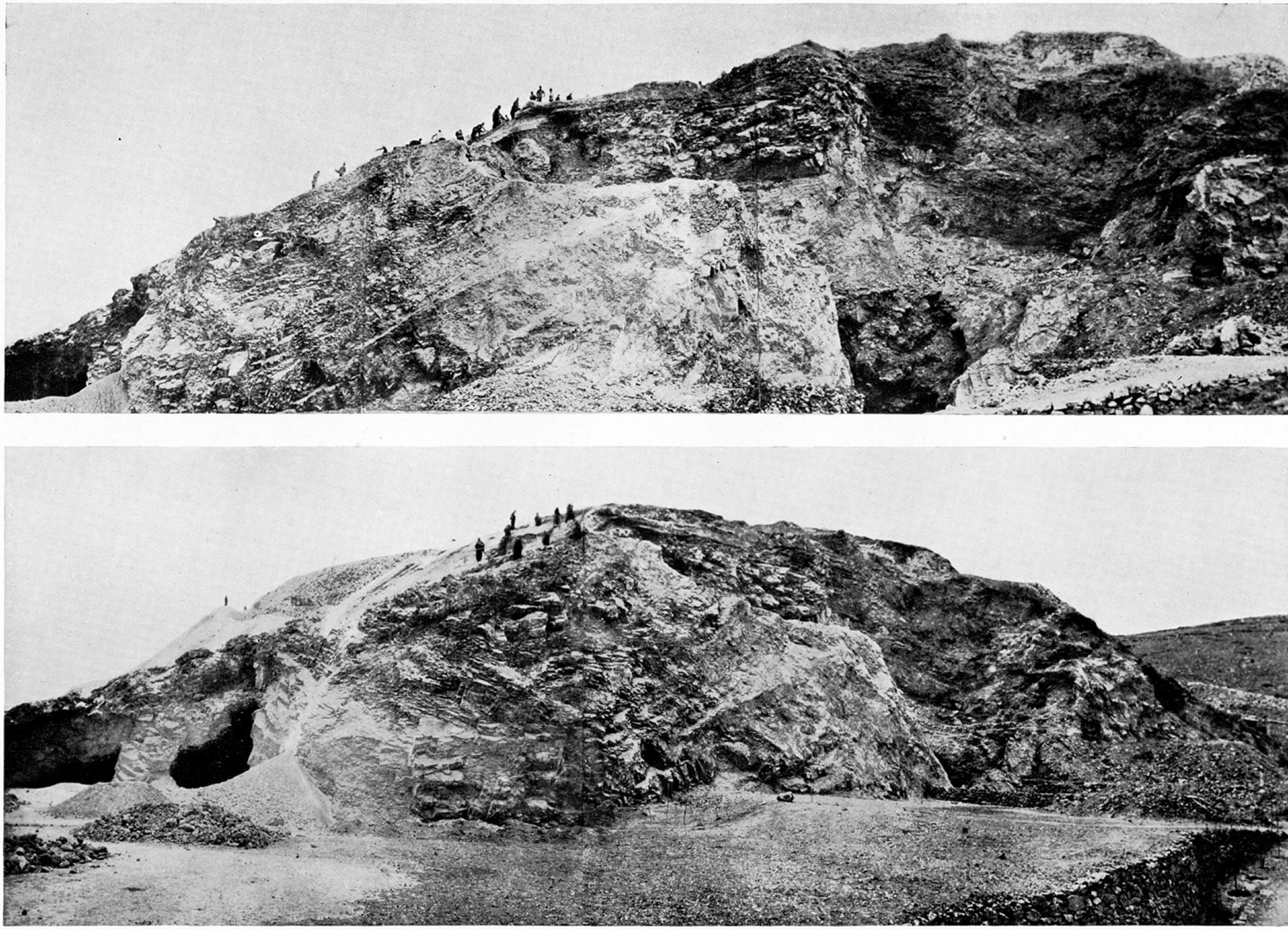

Plate 8.

Two wide angle near-views of the excavations from the north-east taken in April, 1932. The relations of the preserved portion of the limestone wall limiting the deposit on the north to the Kotzetang and Main Deposit areas are evident (*cf.* fig. 29). In the upper figure the massive blocks of brecciated limestone earlier referred to as "Collapsed roof" (Teilhard and Young, 1930) in the eastern part of Layer 3 of the Main Deposit are clearly to be observed (*cf.* fig. 30).

PLATE 9.

Wide angle photograph of the south face of the trench cut in the floor of Kotzetang cave in 1931. The original floor level of the Kotzetang is to be seen in the shadow at the top of the photograph and the scale may be gauged by the rod which is about 3 metres in length. The dark layers at the bottom of the photograph are the red, yellow, and black coloured laminæ of Cultural Zone C (Quartz Horizon 2 of PEI, 1931, *c*), and on a level with the rod the irregularly compressed laminæ of Cultural Zone B are to be recognized (*cf*. fig. 30).

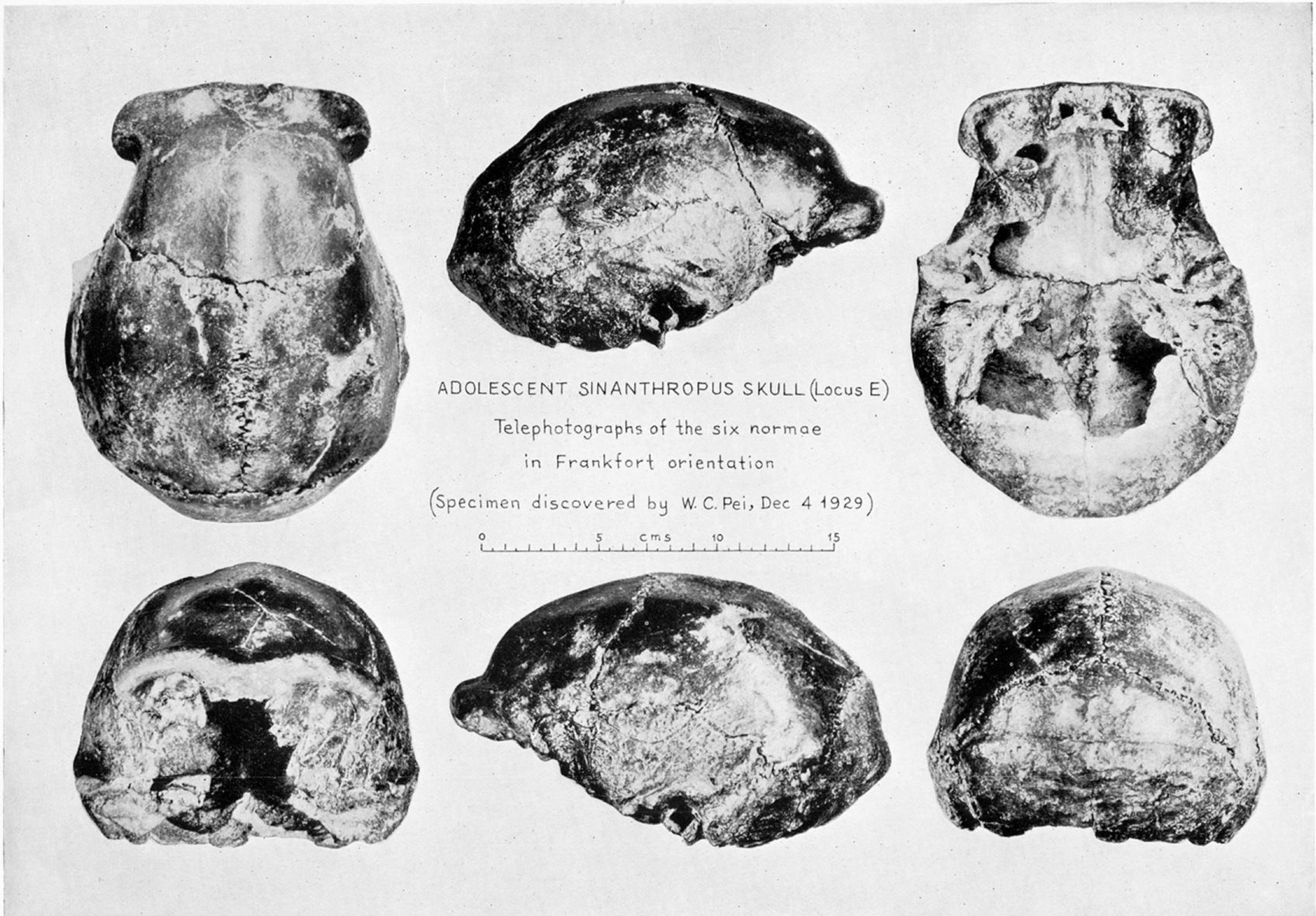

Plate 10.

The six normæ of the adolescent *Sinanthropus* Locus E skull.

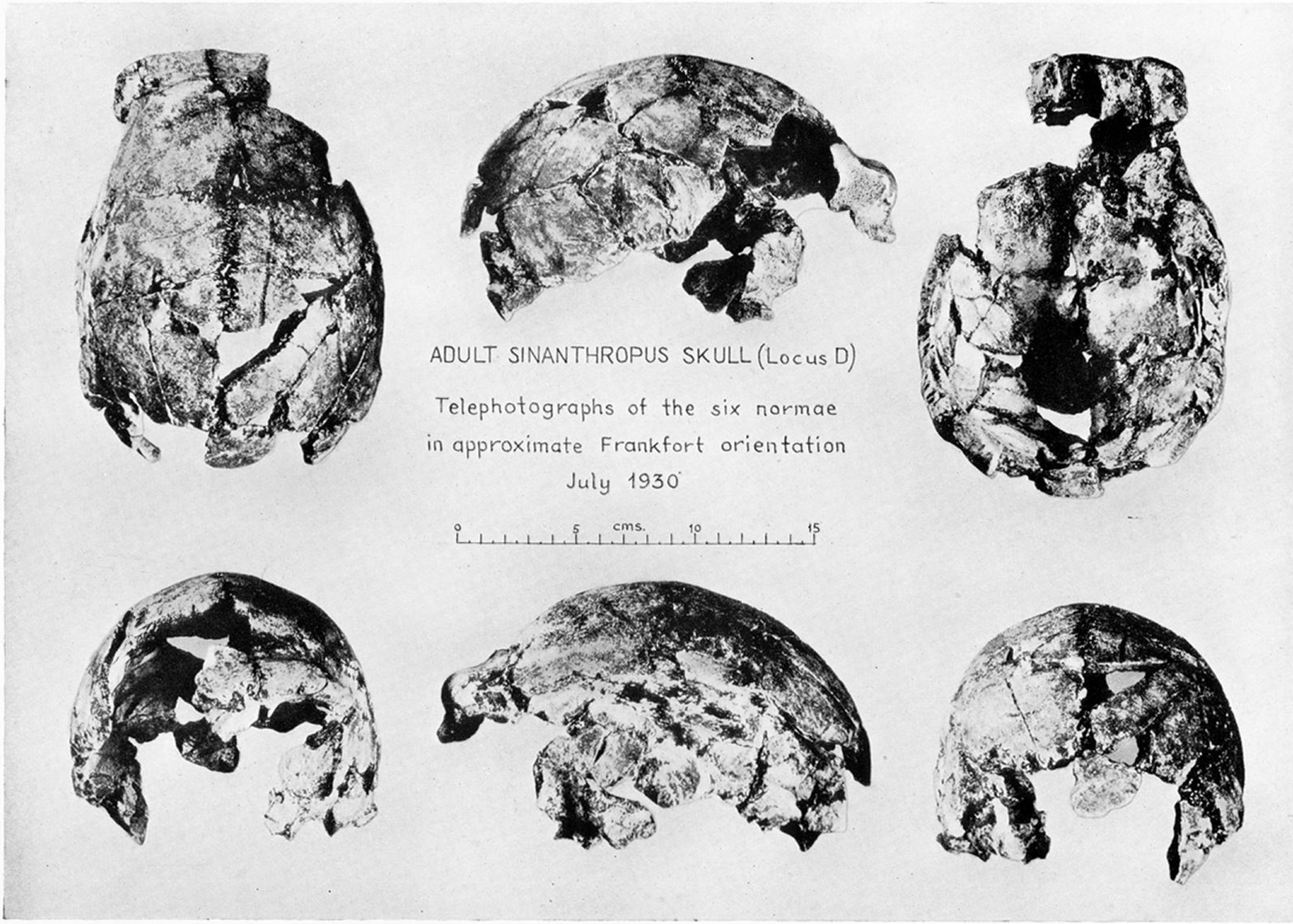

Plate 11.

The six normæ of the adolescent *Sinanthropus* Locus D skull.

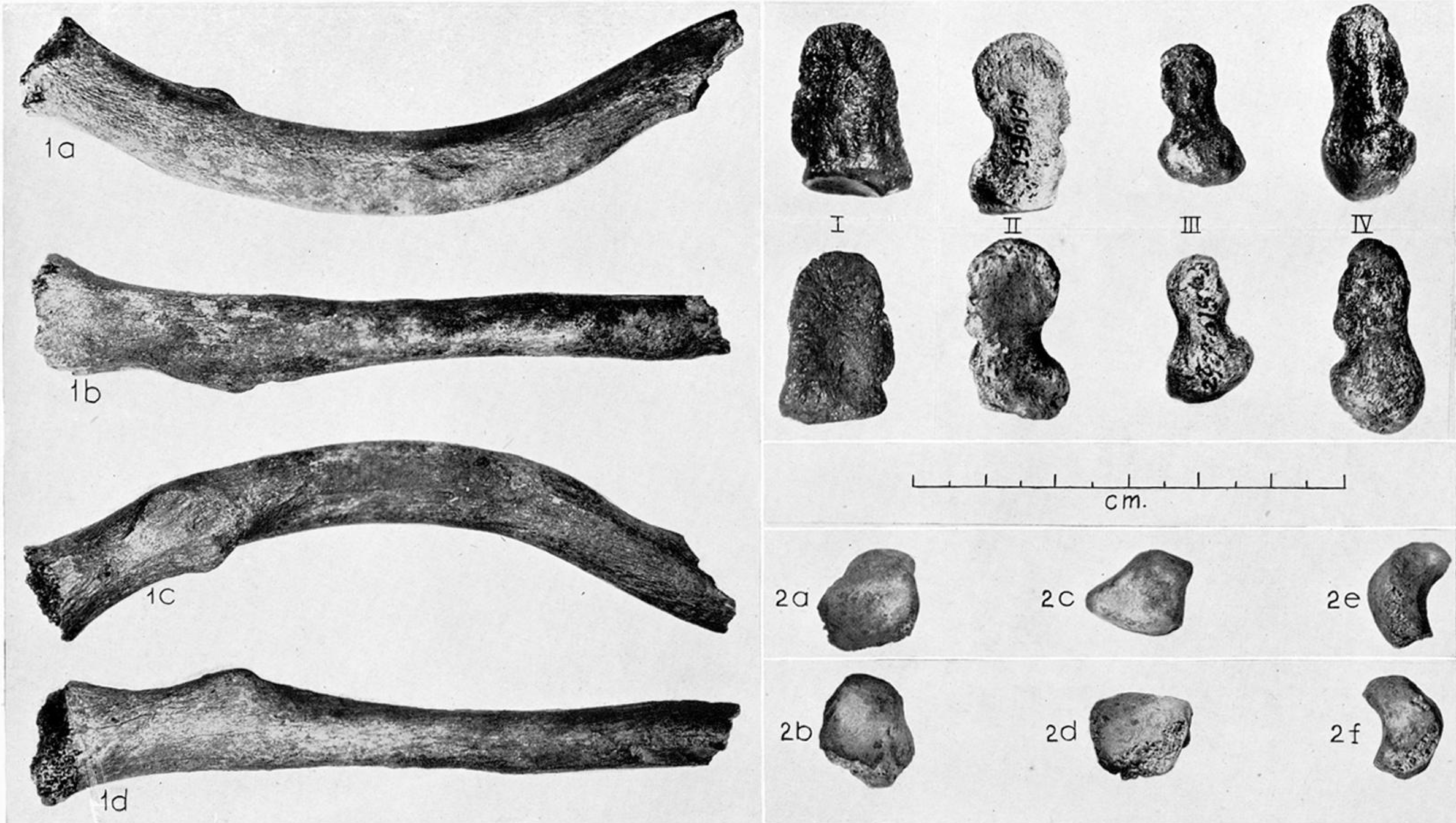

PLATE 12.

FIGS. 1A, 1B, 1C, and 1D, respectively, views of the superior, anterior, inferior, and posterior surfaces of the left clavicle fragment of *Sinanthropus*, nat. size. Figs. 2A, 2B, 2C, 2D, 2E, and 2F, respectively, views of the proximal, distal, dorsal, ventral, radial, and ulnar surfaces of the left os lunatum of *Sinanthropus*, nat. size: orientation: in *a*, *b*, *e*, and *f* the dorsal non-articular surface is towards the top of the page; in *c* and *d* the radial (navicular) surface is to the right; nat. size. Figs. I, II, III, and IV show in the upper row dorsal, and in the lower plantar views of the four *ossa incerta*, nat. size.

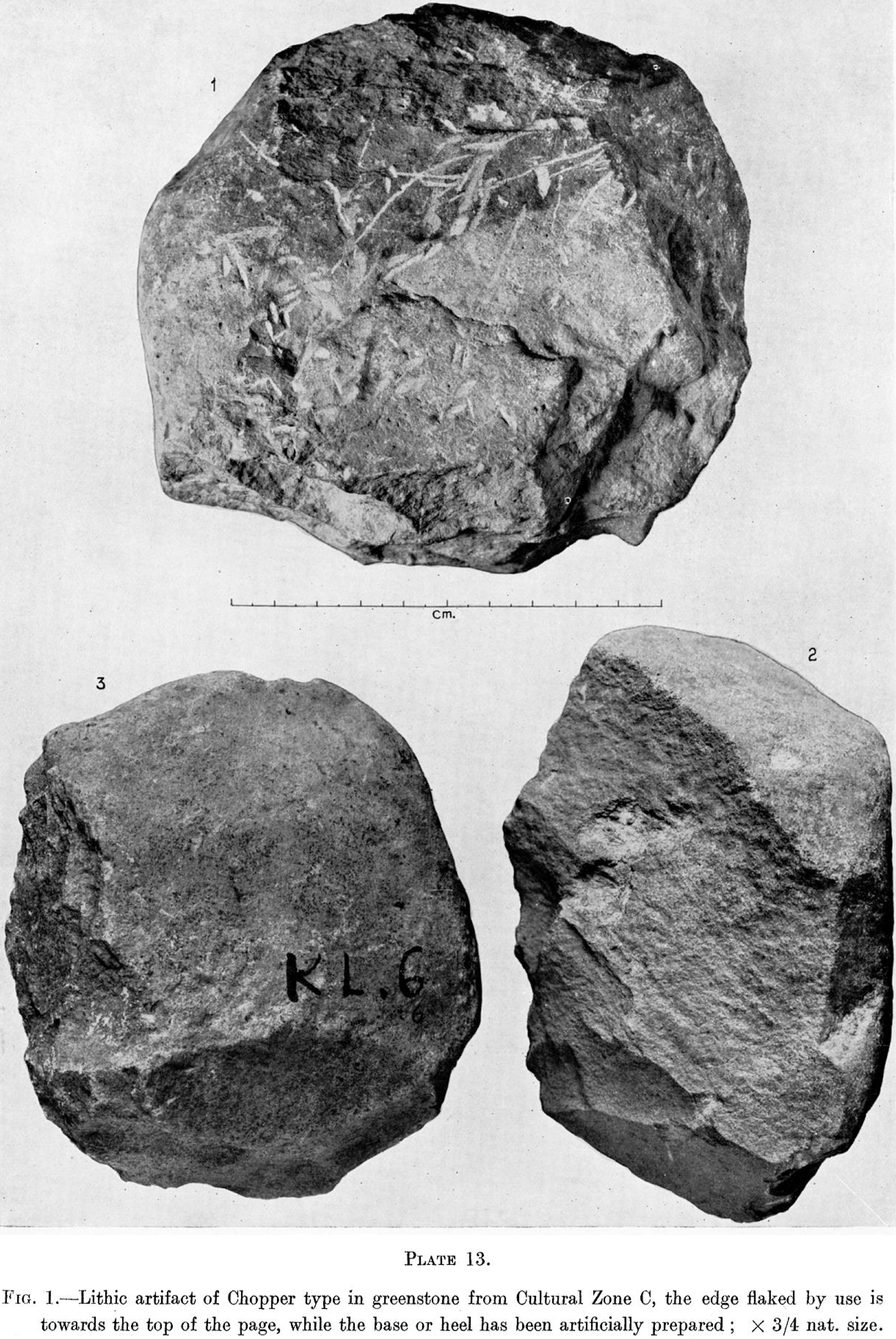

PLATE 13.

FIG. 1.—Lithic artifact of Chopper type in greenstone from Cultural Zone C, the edge flaked by use is towards the top of the page, while the base or heel has been artificially prepared ; × 3/4 nat. size. Fig. 2.—Lithic artifact of Chopper type in greenstone from Cultural Zone C showing evidences of a more or less prepared edge (left) while the heel is naturally rounded ; × 3/4 nat. size. Fig. 3.—Lithic artifact of Chopper type in greenstone from Cultural Zone B with a prepared heel towards the bottom of the page and an upper edge flaked by use ; × 3/4 nat. size.

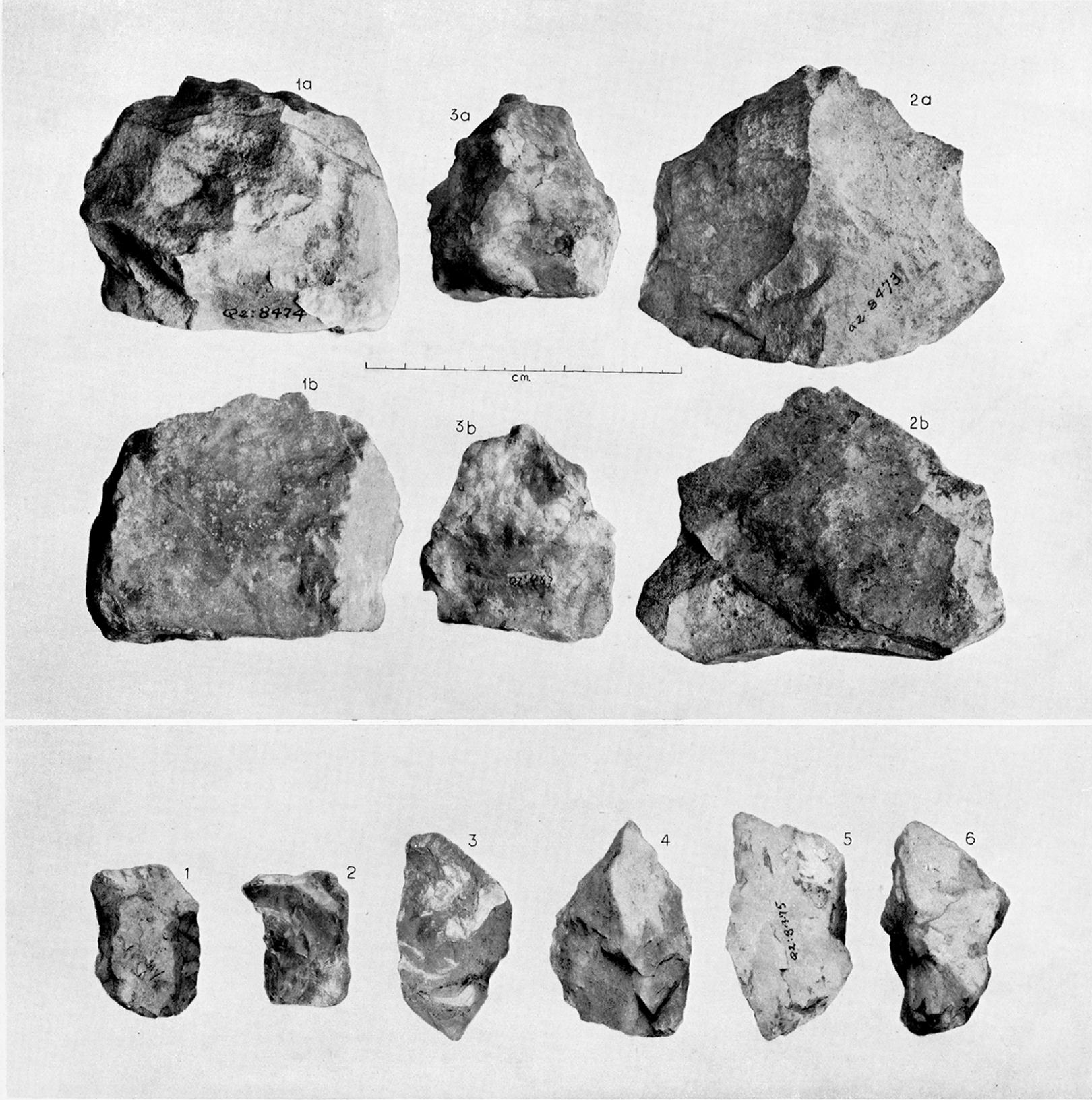

PLATE 14.

(Upper). Three lithic artifacts of the Core type from Cultural Zone C, all at × 3/4 nat. size. Figs. 1A and 1B, respectively, views of the upper and lower surface of an artifact in partly metamorphosed limestone, on the lower surface of which are to be observed the white bruise marks left as the result of many blows, the marks of those which produced the characteristically broken upper surface all being beautifully preserved. Figs. 2A and 2B, respectively, views of the upper and lower surface of another artifact in partly metamorphosed limestone, in which the superficial likeness to some implement of Mousterian type is particularly obvious, but on which likewise the marks are preserved of the blows which served to produce its implement-like facies as well as those which did not result in such fracture. Figs. 3A and 3B, respectively, views of the upper and lower surface of a conical core in vein quartz on the lower surface of which numerous bruise marks are to be observed among which are evident the traces of those which produced the characteristically worked or fractured upper surface.

(Lower). Photographs of six quartz artifacts of the Complex Scraper or Scratcher type, all from Cultural Zone C, all nat. size. Rostrate types are illustrated in figs. 1 and 2, the former being of vein quartz, the latter of beautifully clear quartz crystal. In each the characteristic " beak " is to be seen, and such an implement may reasonably be referred to as having been used by a right-handed individual. Figs. 3, 4, 5, and 6 represent artifacts of the Pointed type, though that shown in fig. 5 approaches to the Rostrate form. With the exception of the artifact shown in fig. 4, the remaining three forms are each evidently asymmetrical to a degree adapting them best for use by the right hand. The artifacts shown in figs. 4, 5, and 6 are of vein quartz, that in fig. 3 being of quartz crystal, the natural surfaces of the latter being clearly evident in the lower part of the photograph. It is to be noted that the bases in artifacts of this type are entirely crude and unprepared in any way.

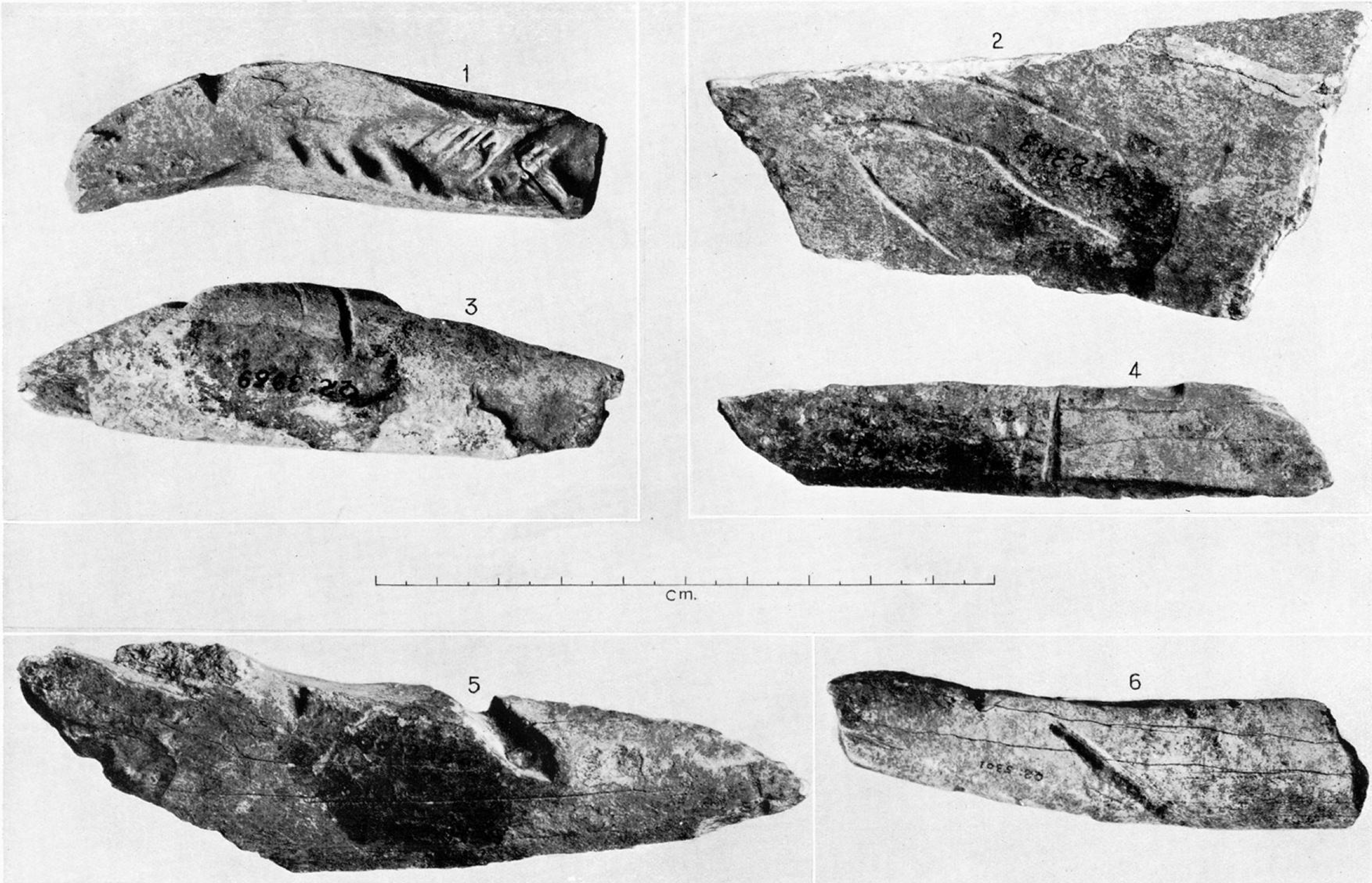

PLATE 15.

Photograph, illustrating a number of specimens of incised and scratched bones from Cultural Zone C (PEI, 1932), all at natural size. In figs. 1 and 5 the marks of angular incisions are clearly evident; in fig. 2 three irregularly curved incisions are evident; in fig. 3 two and in fig. 4 three parallel and straight incisions are to be seen. In fig. 6 the incision has evidently been produced at a single stroke by some hard irregularly pointed implement (BLACK and others, 1933, fig. 81).