slightly poorer in iron than Fe_9S_{10}. If we assume a linear relation between the displacement of superstructure reflections and composition, the deviation from the stoichiometric compositions is 0.02 and 0.03 atomic percent iron for the Ongul and Outokumpu crystals, respectively.

Based on the experimental results on natural and synthetic pyrrhotites mentioned above, it is necessary to examine whether the solid solutions between $Fe_{11}S_{12}$ and $Fe_{10}S_{11}$, and between $Fe_{10}S_{11}$ and Fe_9S_{10} are really stable in nature as is widely accepted (*1, 5, 8*).

Before explaining this question, we shall consider why the displacements of the superstructure reflections take place in natural pyrrhotites. First we must admit the fact that in sulfides a small change of composition in an essentially stoichiometric compound with a superstructure generally results in a continuous change of the cell dimensions, keeping the superstructure reflections at Bragg positions. In such a case, atoms are randomly added on or subtracted from the lattice sites of the original stoichiometric compound. On the other hand, the displacements of the superstructure reflections, observed in essentially stoichiometric pyrrhotites, are considered due to the fact that addition or subtraction of metal atoms takes place by statistical insertion or extraction of completely filled metal layers, retaining the arrangement of the vacant sites in the original structure. In this case, a large deviation from the stoichiometric composition seems difficult, because it must affect the original arrangements of the vacant sites. The Ongul and Outokumpu pyrrhotites seem to indicate that the variation in composition of the stable phases is possible by 0.03 atomic percent iron about the stoichiometric compositions as mentioned above.

Thus the structural consideration of the nonintegral types of pyrrhotite seems unfavorable to the stability of the solid solution over a wide composition range. In fact, Mukaiyama and Izawa (*17*) noticed the broadening of reflections in the powder patterns of many natural pyrrhotites belonging to the solid solutions in question. They observed lamellar and perthite-like textures for these pyrrhotites under the microscope and recognized the existence of phases with slightly different compositions. In addition, the superstructure reflections such as 101 and 102 of the hexagonal natural pyrrhotites (*1*) are not explained by the continuous solid solutions of the nonintegral type observed for the synthetic crystals.

Thus the solid solutions are considered to be metastable and to change to the essentially integral types (*4*) with very narrow ranges about the stoichiometric compositions. This conclusion is also in accordance with the results obtained for the quenched nonintegral types in the Fe-S system (*4, 16*) and for the digenite-type solid solution in the Cu-S system (*12, 18*).

NOBUO MORIMOTO
HIROMOTO NAKAZAWA
KATSUHISA NISHIGUCHI
MASAYASU TOKONAMI
Institute of Scientific and Industrial Research, Osaka University, Suita, Osaka 565, Japan

References and Notes

1. R. H. Carpenter and G. A. Desborough, *Amer. Mineralogist* **49**, 1350 (1964).
2. M. Corlett, *Z. Krist.* **126**, 124 (1968).
3. M. E. Fleet and N. MaCrae, *Can. Mineralogist* **9**, 699 (1969).
4. N. Morimoto and H. Nakazawa, *Science* **161**, 577 (1968).
5. R. A. Yund and H. T. Hall, *Mater. Res. Bull.* **3**, 779 (1968).
6. L. G. Berry and R. H. Thompson, *Geol. Soc. Amer. Mem.* **85**, 61 (1962).
7. The d_s(*hkl*) represents the d-values of the superstructure reflections *hkl*, expressed by the orthohexagonal supercell, and should be distinguished from the d(*hk·l*) of the main reflections, *hk·l*, expressed by the hexagonal subcell of the *NiAs* type.
8. R. G. Arnold, *Econ. Geol.* **64**, 405 (1969).
9. G. Shibuya and K. Kinosaki, *J. Mineral. Soc. Jap.* **9**, 115 (1969) (abstract).
10. N. Morimoto, K. Nishiguchi, H. Nakazawa, G. Shibuya, *Jap. Ass. Mineral Petrol. Econ. Geol. J.* **61**, 171 (1969) (abstract).
11. R. G. Arnold, *Amer. Mineralogist* **47**, 105 (1962).
12. N. Morimoto and K. Koto, *ibid.* **55**, 106 (1970).
13. K. von Gehlen and H. Piller, *Mineral. Mag.* **35**, 335 (1965).
14. E. F. Bertaut, *Acta Cryst.* **6**, 557 (1953).
15. S. Andersson and L. Jahnberg, *Arkiv Kemi* **21**, 413 (1963).
16. H. Nakazawa and N. Morimoto, in preparation.
17. H. Mukaiyama and E. Izawa, *J. Mining Inst. Kyushu* **34**, 194 (1966).
18. N. Morimoto, in *Volcanism and Ore Genesis in Japan*, T. Tatsumi Ed. (Univ. of Tokyo Press, Tokyo, in press).
19. We thank G. Shibuya, T. Tatsumi, and Mabel Corlett for providing us with the specimens from Ongul, Outokumpu, and Kisbanya, respectively. We thank G. Kullerud and L. A. Taylor for reviewing the manuscript and advising us of the first description of the 6*C* type of pyrrhotite, by Fleet and MaCrae (*3*).

6 January 1970

■

Australopithecine Endocast (Taung Specimen, 1924): A New Volume Determination

Abstract. *A redetermination of endocranial volume of the original 1924 Taung australopithecine described by Dart indicates a volume of 405 cubic centimeters, rather than the 525 cubic centimeters published earlier. The adult volume is estimated to have been 440 cubic centimeters. This value, plus other redeterminations of australopithecine endocasts, lowers the average to 442 cubic centimeters, and increase the likelihood of statistically significant differences from both robust australopithecines and the Olduvai Gorge hominid No. 7.*

In the course of an investigation of the endocranial remains of the South African australopithecines, it became apparent that the endocranial volumes already published (*1*), particularly that of the Taung child's endocast, required more accurate determinations. The reasons for this are threefold: (i) the actual methods of past volumetric determinations have not been adequately described; (ii) the published value for the Taung endocast, discovered and described by Dart in 1925, is given as 525 cm^3, a value which seemed clearly high to me when I examined both casts and the original; (iii) a recent spate of articles (*2*) have appeared debating the significance of the Olduvai specimen No. 7, using the original values of australopithecine endocranial capacity, which are, in my opinion, incorrect. With the kind permission and invitation of Professor Tobias, a full study of the South African fossil endocasts was undertaken, and this report covers the results on the Taung endocast, for which three different reconstructions of a complete hemi-endocast were made.

A mold was first made of the original specimen, and several plaster of paris casts were obtained. These casts were carefully checked against the original, and all measurements were found to be accurate within 0.1 mm. The next step in the reconstruction was to ascertain the midsagittal plane accurately, since it appeared upon close examination that previous casts were faulty in this respect. Since a plane can be defined by a minimum of three points, it was decided to select three points reasonably spaced apart from each other along the median sagittal groove. By setting the cast on its convex side on a flat and level surface, and using three fine-pointed spikes in the same plane as the flat surface, it was possible to orient the casts such that the

Table 1. New and previous calculations of the endocranial volumes of the South African australopithecines.

Specimen	Volume (cm^3)	
	This study	Previous study
Taung	440*	525 to 600
STS 60 (Ples. 1)	428	436
STS 5 (Ples. 5)	485	480
STS 19/58 (Ples. 8)	436	550 to 570
STS 71 (Ples. 7)	428	480 to 520
MLD 37/38	435	480
Olduvai hominid 5†	530	530
SK 1585	530	

* Calculated adult volume. † "Zinj."

three points and pointers perfectly coincided. Once this was done, and the cast made stable with Plasticine, it was a simple matter to scribe a very thin line around the available circumference of the cast.

Following this, the excess broken surface was sanded down exactly to the scribed line. Next, the petrosal fossa was cut out to approximate the cleft left by the petrous portion of the temporal bone, filled with breccia in the original specimen. In addition, a small segment of plaster was carved away in the sylvian fissure region, representing adhering bone matrix on the original endocast. The casts were next totally immersed in dilute Glyptal until no further air bubbles arose, and when dried, were coated with a thicker solution of Glyptal, and then immersed in water to make certain no further bubbles arose, indicating a perfect waterproof surface. The casts were then measured again, and no differences were found in measurements.

By using the frontal portion of the endocast still imbedded in the facial fragment as a guide, and the frontal contours of the endocast, a frontal pole portion was made of Plasticine and mounted on the treated endocast. Each endocast was reconstructed afresh, the only difference being in the orbital rostrum, which is of no significant volumetric value. Additional Plasticine reconstructions were added to the inferomedial aspect of the cerebellum, the medulla to the level of the foramen magnum, the anterior tip of the temporal lobe, a small portion of the sigmoid sinus, the lateral surface of the posterior frontal and anterior parietal lobes, and various small pits and depressions. In this way, each hemi-endocast was fully reconstructed. Finally, prior to volume determination by water displacement, the Plasticine surfaces were waterproofed and checked by immersion.

Each cast was measured five times in a 500-ml beaker filled with an arbitrary volume of water, and placed on a flat, level surface with a strip of translucent tape running vertically on the beaker. The endocast was first wetted under a faucet, shaken to remove excess water, and immersed with fine string into the beaker. The resulting level, after complete immersion, was marked on the tape with a fine pencil line at both upper and lower meniscus levels with the eyes parallel to the level of the menisci. The endocast was then removed, and excess water was shaken carefully back into the beaker. By the use of graduated cylinders marked to 1 cm^3, water was replaced into the beaker until the meniscal levels reached the levels marked on the tape, thus giving an accurate indication of the volume of water displaced by the endocast. This was repeated five times for each endocast. The total volume was calculated by assuming perfect cerebral symmetry and multiplying the volume figure for the hemi-endocast by two. Almost all volume determinations were within 1 to 3 cm^3 of each other, and the volume taken up by the string was less than 0.5 cm^3. The average of the first reconstruction was 404 cm^3, the second was 398 cm^3, and the third was 406 cm^3.

Some special remarks are necessary at this point, since in my opinion not all reconstructions were of equal merit. First, reconstruction No. 2 should be deleted from further consideration because the midline surface was slightly oversanded, and the temporal tip was found to have been made too thick when compared back to the fragment still residing in the original facial fragment. The first and third reconstructions were more acurate, particularly the first.

Second, while interpretation of the true midline is made somewhat difficult by prior preparation and indistinctness along parts of its length, the midline chosen matches perfectly a midline obtained by using all midline landmarks on the combined face, frontal bone, and endocast, a check performed independently by Tobias, Alun Hughes, and myself. Nevertheless, to check for the amount of possible error, the following was done. The flat midline surface of reconstruction No. 1 was placed on good tracing paper, and its outline was traced. A planimeter was then used to obtain the surface area enclosed. By multiplying this area by a thickness of 1 mm, a probable value of error was determined. Seven such readings were made, resulting in an average volume of exactly 7 cm^3, ranging between 6.98 and 7.03 cm^3. Thus even if the midline were incorrectly chosen within 1 mm, it would make no more than a difference of 7 cm^3 in the final volume. The independent check mentioned above showed that the midsagittal plane chosen was well within 1 mm.

Third, some other figures are of interest. On reconstruction No. 3, the unreconstructed cast, sanded to true midsagittal plane, gave a volume of 192 cm^3. With removal of the petrosal area and sylvian fragment, the volume was 186 cm^3. The frontal piece reconstructed measured about 15 cm^3. Thus, while some variations in volume might occur in reconstructed portions, they are quite minor, suggesting that the volumes obtained in this work are very accurate.

On the basis of the teeth of the Taung specimen, Tobias (*3*) has calculated that this specimen had reached 92 percent of its total adult volume. As there is no basis for doubting this assessment, the total adult volume of the Taung endocast should be given as 440 cm^3.

Five other gracile australopithecine endocasts were reexamined by me, and volumes were determined with different methods (*4*) (see Table 1). Of these, specimens STS 5 and STS 60 were found to be almost exactly as previously published, 485 and 436 cm^3 respectively. Specimen MLD 37/38 was calculated to be 435 cm^3 rather than the

Table 2. Student's *t*-test values and probabilities of significance of differences in various comparisons of endocranial volumes.

Comparison	d.f.	*t*	*p*
Gracile vs. robust	6	6.69	<.001
Gracile and robust combined vs. Olduvai hominid No. 7	7	4.07	<.01, >.001
Gracile vs. Olduvai hominid No. 7	5	9+	<.0005
Robust vs. Olduvai hominid No. 7*	10	3+	<.01, >.001
752-cm^3 male gorilla vs. average 550-cm^3 male gorilla (*10, 11*) sample	62	3.26	<.01, >.001

* Assumes robust average = 530 cm^3; $N = 6$; S.D. = 53; coefficient of variation = 10; further assumes Olduvai homind No. 7 average = 657 cm^3; $N = 6$; S.D. = 65; coefficient of variation = 10.

480 cm^3 value given by Dart (*5*). Specimen STS 19 was redetermined by using a partial endocast method on the cranial base, and using ratios determined on those australopithecines having the same area complete (*6*). The variation was less than 2 percent, and a volume of 436 cm^3 was obtained. Specimen STS 71 (Ples. Trans. No. 8) (*7*) was found to be 428 cm^3 after reconstruction. This results in a gracile australopithecine average of 442 cm^3 for cranial capacity, with a standard deviation of 21.59, and a coefficient of variation of 4.88 (*8*). When the values of the robust specimens, *Australopithecus* ("Zinj") *boisei* and the SX 1585 briefly described by Brain (*9*), both 530 cm^3, are taken into consideration, the combined average is 464 cm^3, with a standard deviation of 44.71, and a coefficient of variation of 9.63.

Table 2 offers a short statistical analysis, using Student's *t*-test (two-tailed). While these values all indicate that the South African australopithecines differ significantly between robust and gracile, and between either and the Olduvai hominid No. 7 ("pre-Zinj"), it would be premature to accept these tests without extreme caution, since the sample sizes are very small. I have included in Table 2 a test between the giant 752-cm^3 gorilla male value (*10*) and those of a large male gorilla sample (*11*), to indicate that it is possible for one specimen to differ significantly from another sample of the same species. Brace (*12*) has suggested that robust and gracile forms are but male and female specimens, that is, that the difference is nothing more than sexual dimorphism. On the basis of the above results, a sexual dimorphism of 16.6 percent would result, given this assumption. This is a most unlikely explanation when it is remembered that the gorilla, a species with extraordinary sexual dimorphism among primates, shows only 16.3 percent dimorphism (*11*).

The conclusions of Wolpoff (*2*), regarding the Olduvai hominid No. 7 as being the same species as the gracile South African form, cannot be supported by these results, as Pilbeam's (*2*) comments show, although these are based on previous incorrect values. While the precise taxonomic differences between robust and gracile forms remain to be determined, these results, plus the considerations of the rest of the morphology of the skull and teeth, and the localities of the finds, all suggest that the difference is most likely specific. It also apears very likely that the Olduvai No. 7 specimen represents a different taxon than either robust or gracile South African australopithecine forms (*13*).

RALPH L. HOLLOWAY
Department of Anthropology,
Columbia University, New York 10027

References and Notes

1. R. Broom and G. W. H. Schepers, *Trans. Mus. Mem. No. 2* (1946); R. Broom, J. T. Robinson, G. W. H. Schepers, *ibid. No. 4* (1950); P. V. Tobias, *S. Afr. J. Sci.* **64**, 81 (1968); R. A. Dart, *Natur. Hist.* **26**, 315 (1926).
2. R. L. Holloway, *Nature* **208**, 205 (1965); **210**, 1108 (1966); M. H. Wolpoff, **223**, 182 (1969); D. R. Pilbeam, **224**, 386 (1969).
3. P. V. Tobias, *Olduvai Gorge* (Cambridge Univ. Press, New York, 1967), vol. 2.
4. A full description of these methods is in preparation for publication elsewhere. In addition to the partial endocast method used on STS 19, other reconstructions were based on four dimensions, and a coefficient was determined from complete endocasts. The validity of this method was first checked on ten chimpanzee and nine gorilla endocasts, and was found to predict cranial capacity within 2 percent.
5. R. A. Dart, *Amer. J. Phys. Anthropol.* **20**, 119 (1962).
6. STS 5, "Zinj," SK 1585, STS 60.
7. R. Broom, J. T. Robinson, G. W. H. Schepers (*1*).
8. These are admittedly lower than expected on the basis of extant pongid samples. This is probably due to both the small sample size of gracile forms, and a bias introduced from using certain gracile forms to estimate the volume of others.
9. C. K. Brain, *S. Afr. J. Sci.* **63**, 378 (1967).
10. A. H. Schultz, *Anthropol. Anz.* **25**, 179 (1962).
11. E. H. Ashton and T. F. Spence, *Proc. Zool. Soc. London* **130**, 169 (1958).
12. C. L. Brace, *Abstracts, Amer. J. Phys. Anthropol.* **31**, 255 (1969).
13. This conclusion is reinforced by certain morphological features of the endocasts which have not been discussed here, but which are currently being studied and will be published in the future.

14. Supported by NSF GS-2300. I am indebted to Professor P. V. Tobias, Mr. Alun Hughes, and Mr. Brian Hume for their support and kindness.

28 January 1970

■

Transcontinental Tidal Gravity Profile across the United States

Abstract. *Data obtained from a transcontinental tidal gravity profile across the United States were analyzed. Results for the principal tidal constituents* M_2 *and* O_1 *have shed light on the long-standing problem of the indirect influence of ocean tides on the solid-earth tide. The profile consists of nine observational stations distributed almost evenly around latitudes 39 to 41 degrees north across the United States. The observed values of the gravimetric factor and the phase were found to depend on the tidal characteristics of the Atlantic and Pacific oceans. There is no observable correlation between tidal gravity parameters and the regional geology. When the influence of ocean tides is taken into account, it is possible for the first time to bring the gravimetric factors and phases for all the stations of a transcontinental network into a consistent system within the framework of the earth tidal theory.*

The solid earth undergoes a periodic tidal deformation, termed "earth tides." This deformation results principally from the attraction of the moon and the sun that manifests itself by a rise and fall of the earth's surface. The magnitude of the elevation change is of the order of 25 cm in the midlatitudes and 50 cm near the equator. The earth tides are greatly influenced by ocean tides, a process that is very complex and often difficult to evaluate because the tidal conditions in open oceans are almost unknown and must be inferred from coastal stations. Extensive efforts were made during the International Geophysical Year (IGY), 1957–58, to carry out long series of earth tidal observations on a worldwide basis. The IGY data clearly indicate the regional differences in the values of the gravimetric factor and the phase (*1*).

A few years ago, the Lamont-Doherty Geological Observatory of Columbia University began a study of spatial variations of tidal gravity directed specifically toward evaluation of the indirect and secondary effects, principally the effects of ocean tides and geological structures, on tidal gravity. The results from a dense network of stations in the New York–New Jersey–Pennsylvania area (*2*) have shown that the amplitude ratio of the M_2 to the O_1 tidal constituents and the phase difference of these two constituents decrease systematically as a function of the station distance from the Atlantic coast.

More recently, a transcontinental tidal gravity profile across the United States was established by Lamont-Doherty; it provided an ideal basis for investigating the influences of the Pacific and Atlantic oceans, and of several major geological provinces, on tidal gravity. The network of the transcontinental profile consists of nine semipermanent observational stations around latitudes 39° to 41°N (Table 1). At least six stations were in simultaneous operation at all times. A long and uninterrupted series of observa-