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Introduction

During September and October, 1966, the author measured a stratigraphic section for a portion of the Omo Beds, as exposed north of Kalam, Ethiopia. Additional field observations were also made at the time in other parts of the lower Omo Basin. Samples were collected for analysis and for radiometric age determination, and the first potassium-argon measurements were made on feldspars from tuffs in this succession in late 1966 and early 1967. As part of the work of the University of Chicago contingent of the Omo Research Expedition, further field work was possible in the main exposures during the summer of 1967, with additional units being added to the stratigraphic section recorded previously. Materials suitable for isotopic age determination were recollected and further potassium-argon measurements were made during the fall of 1967. These results substantiated and extended the earlier findings.

Distribution of Late Cenozoic deposits in the lower Omo basin

At least two distinct sequences of later Cenozoic sediments exist in the basin of the lower Omo River. The younger sequence, termed the Kibish Formation (Butzer, Brown, and Thurber, this volume), is best exposed about ten kilometers east of the Kibish Police Post. It is also generally present on a surface of low relief as a thin veneer covering the truncated edges of the older sediments. Older sediments also outcrop in areas where the relationship to the Kibish Formation is unknown.

Deposits predating the Kibish Formation outcrop in several distinct localities. These include 1) the main exposures between the Korath Range and the Omo River, 2) exposures northwest of Kalam, 3) exposures south of the Usno-Omo

(1) Omo Research Expedition (University of Chicago), Contribution No. 2. A version of this paper was first presented at the VIth Pan-African Congress on Prehistory and Quaternary Studies, held in Dakar, December 1967.

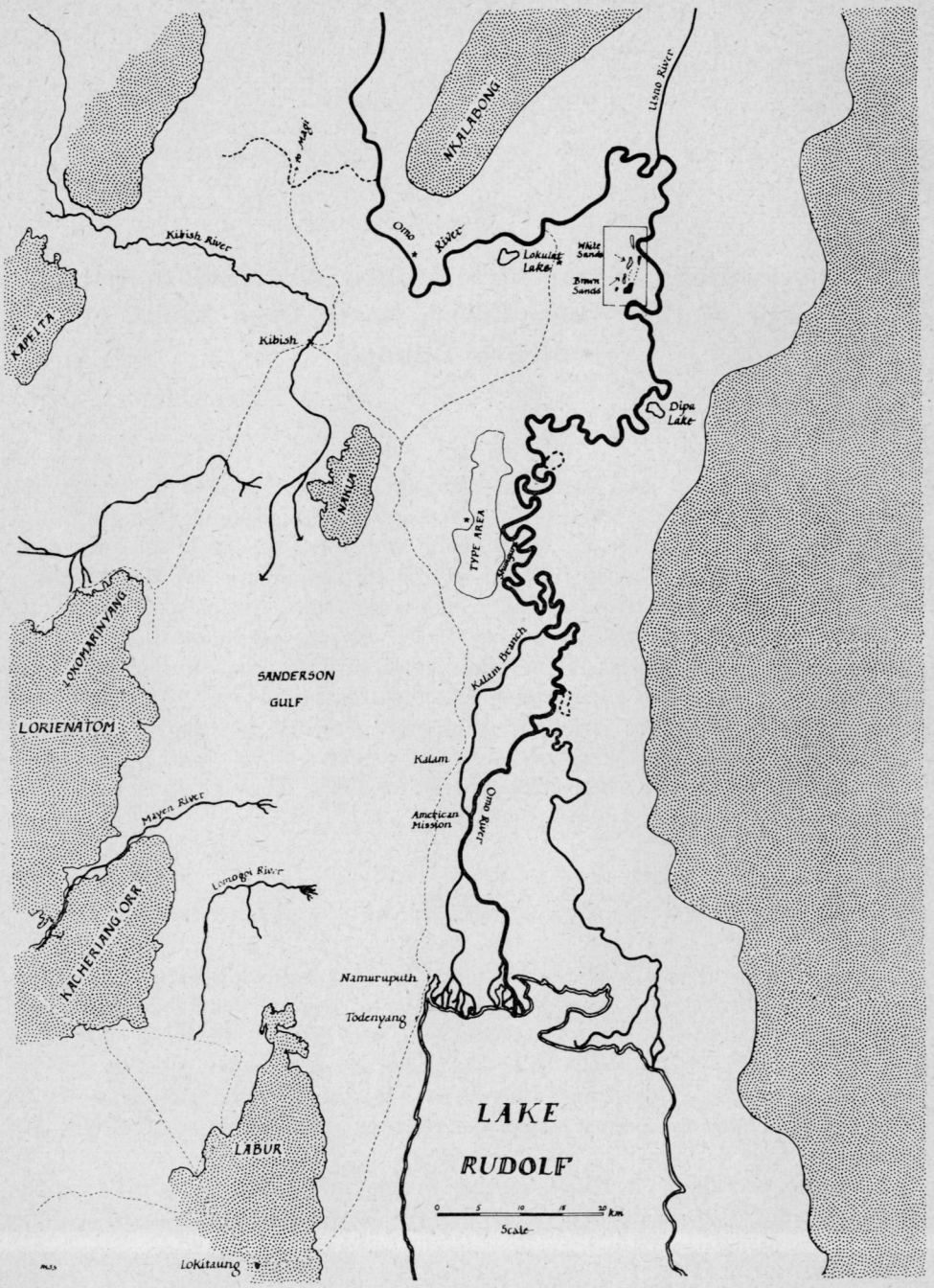

FIG. 1. - Generalized map of the lower Omo basin, southern Ethiopia.

confluence, 4) exposures at the southwest extension of the Nkalabong massif, and 5) minor outcrops on the northern slopes of Nkalabong, 6) at Liwan, and 7) on the northern flank of Labur in the southwest portion of the basin (Fig. 1).

On Arambourg's (1943) geological map the exposures between the Korath Range and the Omo River, and those northwest of Kalam (see map) were included in his earlier lacustrine deposits. Sediments of the same stratigraphic sequence are undoubtedly exposed in both areas, but precise stratigraphic relationships between the two areas are not known. Although poor in fossils, the sedimentary sequence northwest of Kalam contains materials suitable for potassium argon dating, and can be tied to the exposures in the type area.

The sediments in the exposures south of the Omo-Usno confluence have yielded an excellent faunal assemblage and their geology has been adequately described by Jean de Heinzelin and the author (this volume). They have been tentatively referred to the Omo Group and given the designation Usno Formation.

Two exposures are related to the Nkalabong massif, one at its southwest end and one on the high plain which extends northward from the mountain. The exposure located on the eastern bank of the Omo River at the southwest end of the mountain was discovered and explored by the Kenyan contingent of the expedition in 1967 and is called Yellow Sands. At this locality a fossiliferous sequence of sediments underlies a basalt flow (see brief description of the Mursi Formation in Butzer and Thurber, 1969). Tuffs believed to belong to this sequence were observed, but did not appear to contain isotopically datable material. The questionable exposures north of Nkalabong are comprised of tuffs and sediments underlying or intercalated with a thick succession of basalts. These basalts lie unconformably on an older group of volcanics. Exposures are very poor and no fossils were observed by the author in the course of reconnaissance there.

The exposures near Liwan are of minor extent, and do not appear fossiliferous. The total thickness of tuffs and tuffaceous sands amounts to perhaps 20 meters.

On the north end of Labur, between Kaieris and Loruth Kaado, there are exposures of a bluish tuff underlain by a coarse feldspathic sand. Some rounded, heavily mineralized bone fragments were noted, but no intact fossils were found.

Stratigraphy of the « Omo Beds » in the Type Area

The most extensive exposures of the Omo Beds (now termed the Shungura formation) lie east of the Korath Range and rise out of the plain north of Kalam to disappear east of the northern end on this range. The exposures are made up of a series of assymetrical ridges which trend north-south and drop off steeply to the east and gently to the west. The beds strike N 0° E to N 20° E, and dip 8°-15° to the west. The essentially homoclinal sequence is transected by *at least* two sets of faults. The most important are normal faults which parallel the strike of the beds and dip steeply (60-70°) to the east. Vertical displacement along any one of these faults probably does not exceed a few hundred meters; however the cumulative displacement is substantially greater. A few of these faults do dip in a westerly direction but are confined to small areas of minor folding.

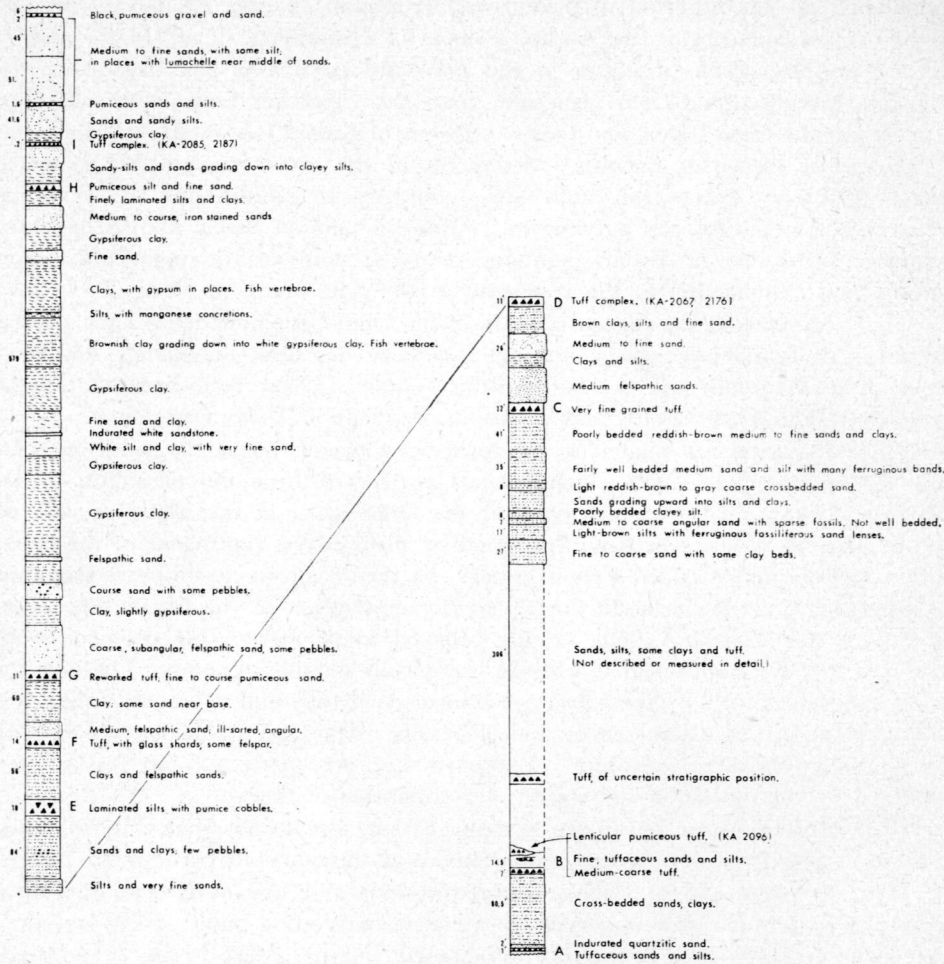

FIG. 2. - Stratigraphic column through the « Omo Beds », southern Ethiopia.

The second set of faults strikes about N 85° E and is thus nearly perpendicular to the major set. The displacement on this set is generally small, with the beds north of the faults usually downfaulted. However the reverse situation has also been observed.

Minor areas of markedly asymmetrical folding have also been observed. In these folds, the eastern limbs of anticlinal structures are much steeper than the western limbs. This folding was probably contemporaneous with the tilting and faulting of the beds. Minor unconformities are numerous in the « Omo Beds », but no major unconformities have been observed.

The « Omo Beds » are predominantly silts, clays, and sands with fine to medium sands being much more prevalent than silts. The sands are generally gray to light brown or even greenish gray. Their dominant minerals are quartz, feldspar and bleached micas. Although most of the sands are extremely friable

there are local patches cemented by iron and manganese oxides, carbonate, or gypsum. Many well preserved but usually disarticulated vertebrate fossils have been eroded from these sands. Current crossbedding is common and reflects a predominantly fluvial environment of deposition.

The clays may be dark reddish brown, greenish, or pale brown, and exhibit marked cracking at the surface. Exposed clays contain gypsum and sometimes halite. The most common fossils are fish vertebrae and fragmentary fish crania. One sandy horizon about 60 cm. thick in a sequence of clays contains ostracods.

Several beds of reworked tuff occur in the « Omo Beds » in these exposures. They are important as reliable marker beds and contain minerals suitable for potassium argon age determination. These tuffs are generally light gray or bluish gray and consist almost wholly of volcanic glass. Quartz and anorthoclase are present in many tuffs, and heavy minerals separated from the pumices include aenigmatite, brown to green sodic amphibole (richterite?), and sodic hedenbergite, which establishes them as alkaline rhyolites. Bluish pumiceous sands which are generally more indurated than the quartzo-feldspathic sands often cap ridges and form the gentle western slopes of hills. Some of these silts and sands show very fine laminations and ripple marks suggesting a lacustrine environment of origin. Others show typical current cross-bedding indicative of fluvial origin. Pumice pebbles up to 2.5 cm. may occur in the coarser beds of these tuffs.

Some of the silts contain rounded pumice cobbles 60 cm. or more in diameter. These pumices consist of relatively fresh glass with abundant anorthoclase phenocrysts.

Above Tuff C the stratigraphic thicknesses were measured directly with a Jacobs staff, and are probably reliable. The portion of the section which is dotted in Figure 2 (below Tuff C) is only intended to be schematic. In this part of the column the thickness was trigonometrically derived from the aerial photographs using attitudes measured in the field. In calculating the thickness of this lower part of the section no structural complexity has been assumed. If faulting has occurred between Tuff C and Tuff B, which is possible, the calculated thickness will most likely be too great, since most of the faults in the section are normal. The approximate total measured thickness is nearly 500 meters. However, since neither the top nor the base of this sequence has been seen, the section in Figure 2 is open ended and the overall thickness may be considerably greater than 500 meters. The relationship of this sequence to any older or younger deposits remains unknown.

Although the tuffaceous units consist predominantly of rhyolitic volcanic detritus, other materials are present to a greater or lesser extent, which is to be expected in a fluvial deposit. The occurrence of the large pumice cobbles (up to 60 cm.) precludes a source from outside the basin, and there are no obvious volcanoes nearby which could have provided the debris. In the headwaters of the Omo River rhyolitic volcanoes exist, both near Jimma (Pagliani, 1940) and south and west of Addis Ababa (Mohr, 1964), which may have been the source for the material deposited in the Omo Beds. In order to mask the normal sediment type of the river, the eruptions which provided the material must have discharged abundant material directly into the river, but exactly where this occurred is unknown.

Potassium-argon age determinations

Cobbles from three stratigraphic horizons yielded excellent materials for radiometric age determination, and at least two more horizons should prove suitable. Relatively coarse (greater than 60 mesh) crystals were used in dating to guard against the possibility of contamination, and care was taken to utilize crystals from within the cobbles only. Prior to argon extraction the crystals were treated with hydrofluoric acid to reduce the atmospheric argon contamination (see Evernden and Curtis, 1965). The stratigraphic positions of the dated specimens is noted in Figure 2.

The results of the potassium-argon age determinations are listed in Table 1. Two of the tuffs were dated twice using samples collected separately (in 1966, and again in 1967) in order to assess the reliability of the data. (Compare KA-2085 and KA-2187; KA-2067 and KA-2176). All of the dates obtained agree sequentially with the established stratigraphy. This result is important since 1) credibility is strengthened by every independent check, and 2) the argument of possible redeposition is ruled out, since, if the tuffs had been redeposited, it is improbable that their radiometric ages would remain sequential in ascending order.

TABLE 1

KA-No.	Horizon	Wt. in Grams	K+ (%)	A^{40} at (%)	Age
KA-2085 . .	Tuff I (2)	5.0010	5.111	Not calculated	1.87 ± .08 m.y.
KA-2187 . .	Tuff I (2)	5.2886	5.182	54.8	1.81 ± .08 m.y.
KA-2067 . .	Tuff D	5.0023	5.151	51.0	2.56 ± .12 m.y.
KA-2176 . .	Tuff D	5.0001	5.432	53.6	2.37 ± .12 m.y.
KA-2096 . .	Tuff B (4)	6.0050	4.625	50.3	3.75 ± .20 m.y.
KA-2094 . .	Basalt, Yellow Sands	10.1667	.828	75.4	4.05 ± .20 m.y.

A further determination (KA-2094) has been made on a whole rock basalt from the Yellow Sands locality. This flow is the top member of the Mursi Formation and overlies the fossiliferous sedimentary sequence at this locality. Although there is no possibility of direct correlation there are certain mammalian taxa there which would indicate an age as old as or older than the oldest known part of the exposed section of the Shungura Formation (L. S. B. Leakey and F. C. Howell, personal communication). Consequently the oldest dates thus far obtained, 3.75 m.y. and 4.05 m.y. are mutually compatible.

Discussion

The upper part of the Omo Beds section in the main exposures has an age slightly exceeding 1.8 m.y. The age of the lava underlying the known bulk of the sediments at Olduvai Gorge is 1.92 m.y. (Evernden and Curtis, 1965;

Grommé and Hay, 1967). It would thus appear that the main portion of the Omo succession of this type area antedates the Olduvai sequence and the upper limit of the Omo Beds as presently known lies close to the lower limit of the Olduvai succession. Patterson (1966; also Patterson and Howells, 1967) has recently reported on the Kanapoi locality, southwest of the southern extremity of Lake Rudolf. The fossiliferous sediments there underlie a basalt flow with reversed polarity of natural remanent magnetization. Potassium-argon ages between 2.9 ± 0.3 m.y. (2 determinations) and 2.5 ± 2 m.y. have been obtained. Thus the fossiliferous sediments at Kanapoi must correlate in some way with the lower part of the Omo succession. The fossiliferous deposits at the Yellow Sands locality are even older to judge by the author's potassium-argon determination on the overlying basalt.

In conclusion, the fossiliferous Omo Beds appear to span the Pliocene-Pleistocene boundary, regardless of which current definition is accepted for that boundary.

ACKNOWLEDMENTS

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ZUSAMMENFASSUNG

Eine geologische Voruntersuchung des Verf. im Jahre 1966, der 1967 weitere Geländearbeit folgte, hat eine grosse Mächtigkeit sowie ein plio-pleistozänes Alter für die bekannten « Omo Beds » des Omobeckens Südwestäthiopiens ermittelt. Insgesamt konnten etwa 500 m. Sedimente und vulkanische Aschengesteine nachgewiesen werden. Kalium-Argon Altersbestimmungen an Feldspaten verschiedener Tufflagen verteilen sich systematisch zwischen etwa 4 mll. J. (nahe der aufgeschlossenen Basis) und etwas weniger als 2 mill. J. (unter den Hängen). Eine weitere aber isolierte Fundstelle am Nordrand des Beckens ist bereits älter als 4 mill. J. Somit reichen die fossilführenden Sedimente des Omobeckens vom ausgehenden Pliozän ins früheste Pleistozän gemäss der verschiedensten üblichen Definitionen der plio-pleistozänen Grenze.

RIASSUNTO

Una ricognizione geologica effettuata dall'Autore nel 1966, insieme a ulteriori lavori sul terreno nel 1967, hanno dimostrato il notevolissimo spessore e l'età plio-pleistocenica degli « Omo Beds » del bacino inferiore dell'Omo nell'Etiopia sud-occidentale. Sono stati rilevati circa 500 metri di sedimenti e piroclastiti. Le misurazioni con il metodo del potassio-argon effettuate su minerali (feldspati) prelevati in diversi orizzonti di ceneri vulcaniche hanno fornito datazioni che si susseguono da circa 4 milioni di anni (presso la base visibile) a poco meno di 2 milioni di anni (sotto la sommità visibile). Un'altra località fossilifera isolata nella parte settentrionale del bacino ha dato un'età di più di 4 milioni di anni. Queste formazioni fossilifere sembrano dunque estendersi dal Pliocene finale al Pleistocene antico, secondo le varie usuali definizioni del limite Pliocene-Pleistocene.