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THE OMO GROUP

THE LOWER OMO BASIN

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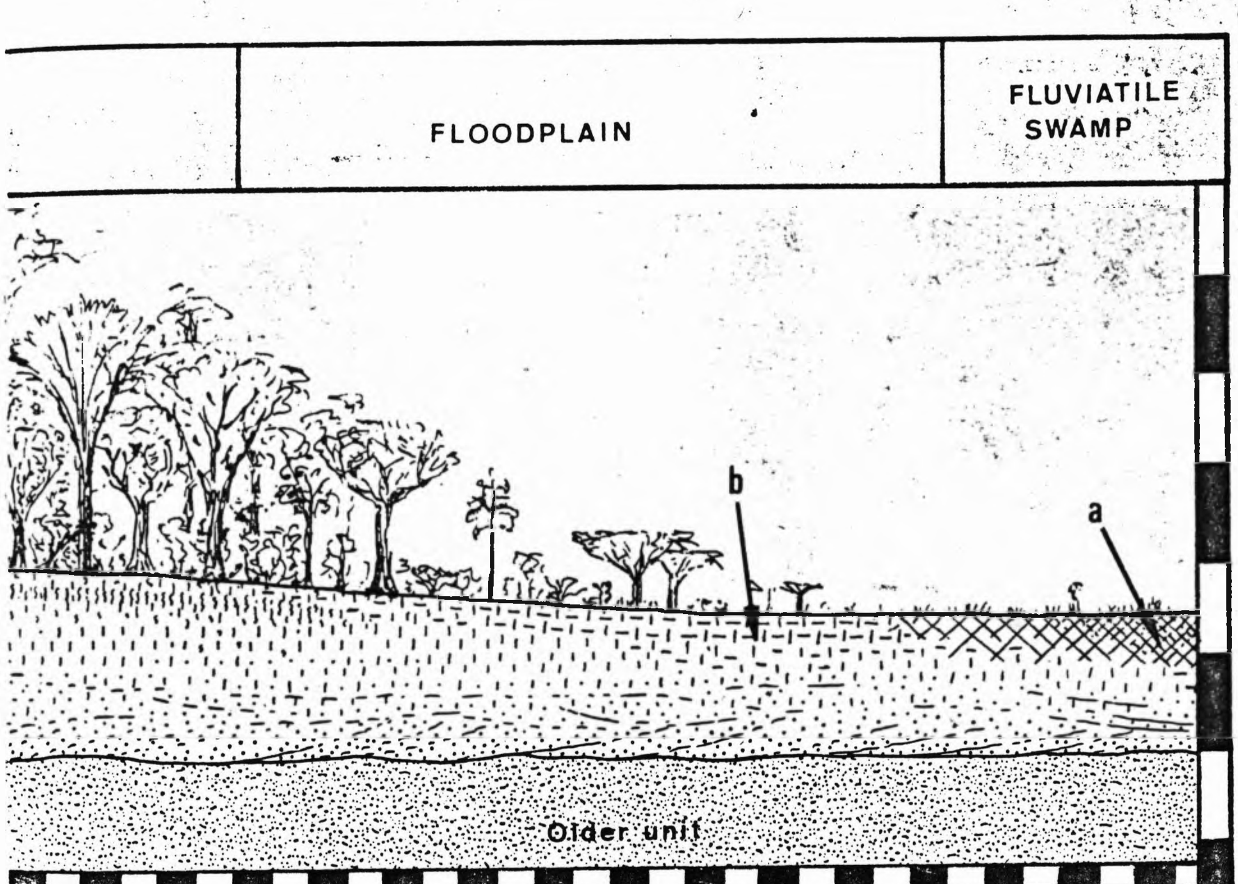

ARCHIVES OF THE INTERNATIONAL OMO RESEARCH EXPEDITION

MUSÉE ROYAL DE L'AFRIQUE CENTRALE – TERVUREN, BELGIQUE
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CHAPTER 2

THE LOWER OMO BASIN

by F.H. BROWN and J. de HEINZELIN

2.1. GENERAL TECTONIC SETTING (F.H. B.)

2.1.1. Substratum

The boundaries of the Lower Omo Basin have been mapped by Fuchs (1939) and by Butzer (1970, 1971) in a general way. The structural features and physiography of the eastern and central part of the Lower Omo Basin are best expressed on the maps of Davidson *et al.* (1973). Walsh and Dodson (1969) have mapped the geology of the North Turkana District of Kenya. East of Lake Turkana the geology is summarized by Vondra and Bowen (1976), and Vondra, Burggraf and White (1978). The Ilemi Triangle in southern Sudan remains poorly known geologically, but some information is presented by Fuchs (1939), and by Arambourg (1943). More recently Baker *et al.* (1972) and Cerling and Powers (1977) have provided general summaries of the structural evolution of this part of East Africa.

The outstanding geomorphic features of the area are the fault-block mountains and highlands which generally trend N-S to NNE-SSW. These include the Labur Hills southwest of the Lower Omo Basin, the Lorienetom and Lokwanamoru Ranges and Kacheriangorr Hills which bound the basin on the west, the Nkalabong Range in the northern part of the lower Omo drainage basin, the Maji escarpment and Maji highlands which bound the basin on the northwest, and the Hammar highlands which bound the basin on the east. These highland areas surround a topographically low area in which Lake Turkana lies, and which extends northward from the lake nearly 100 km north of the Nkalabong Range as a great reentrant in the Ethiopian plateau. All of the highland areas have probably been uplifted during several periods of tectonic activity, and here we wish only to outline the major periods of activity, and to describe the geology of the surrounding areas in a general way.

The oldest rocks in the area are metamorphic and presumed to be pre-Cambrian in age. They consist of biotite and hornblende gneisses, quartzo-feldspathic gneisses, marbles, and mafic gneisses and granulites. The largest exposure of these rocks occurs in the Hammar Range, a smaller area is found on Labur, and tiny but important patches are seen underlying the volcanic rocks of the Nkalabong Range and the Maji highlands. A single large metamorphic block (ca 1 m in diameter) was observed at the fault truncating the basalts at the southern end of the Usno Formation.

In the northern part of the Hammar mountains, a sedimentary unit perhaps 8 m thick which consists of red sandstones and conglomerates separates the metamorphic basement from the overlying volcanic rocks (Davidson *et al.*, 1973). In the southern part of this range,

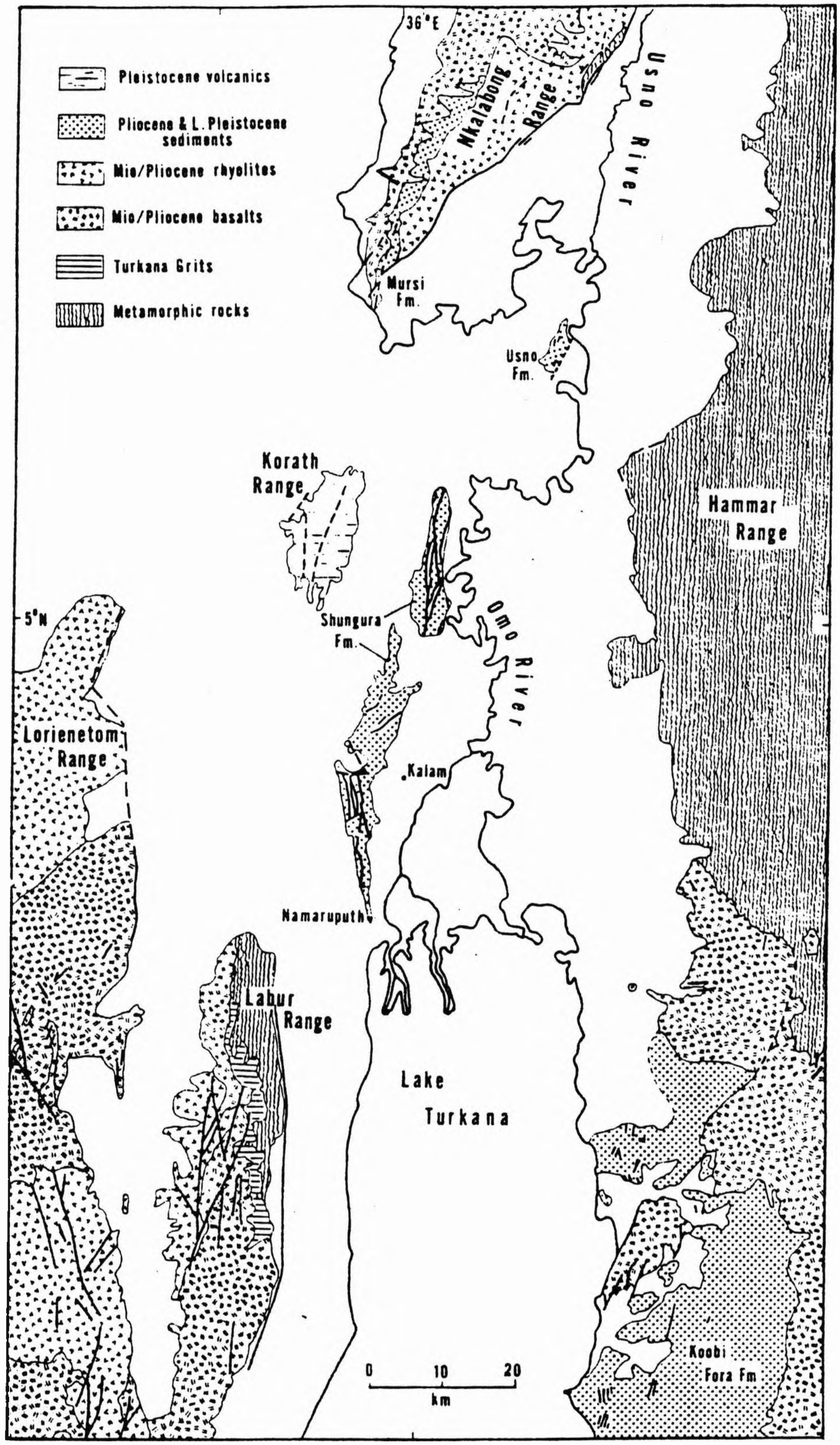

Fig. 1.- Distribution of rock types and major structural features.

the basalts east of the northern end of Lake Turkana are separated from the underlying basement by a buff colored sand. Farther to the east, between Lake Stephanie (Chew Bahir) and Lake Turkana, there are sediments interbedded with Miocene volcanic rocks (Fitch and Miller, 1976).

On Labur, the «Turkana Grits» directly overlie the basement, and are succeeded by basalts and other basic rocks, and these in turn are overlain by rhyolites. The deposits termed the «Turkana Grits» are of uncertain age. Most workers have assigned them to the Miocene on the basis of lithologic similarity to sediments near Lodwar (Losodok) which contain a Miocene fauna. Arambourg and Wolff (1969) however, assign them a Mesozoic age on the basis of a humerus which they regard as that of a sauropod dinosaur. If Arambourg and Wolff are correct in their assessment of this specimen, then the most probable age of the Turkana Grits on Labur is Cretaceous because in addition to the dinosaur fossil, silicified logs of *Dryoxylon*, an angiosperm, occur in these sediments. The oldest date on the overlying lavas (32 m.y.) seems to lend support to the proposition of Arambourg and Wolff, because if this date is correct, the underlying sediments should be no younger than Oligocene in age, and could not in any case be correlated with the Turkana Grits at Losodok. Younger basaltic and phonolitic lavas in North Turkana have ages ranging from 23.5 to 12.5 m.y., however the youngest rocks from this sequence, the rhyolites, have not been dated.

East of Lake Turkana, volcanic rocks lie either directly on basement, or are separated from it by a thin sedimentary sequence. The oldest lavas in this area are near 17 m.y. in age and are basalts. Rhyolitic ignimbrites follow about 16 m.y. ago. Another group of basalts and related ignimbrites ranges in age from 11.6 to 14.1 m.y. The rhyolitic domes of Kubi Algi and Derati were probably erupted about 7.5 m.y. ago. About 3 to 4 million years ago basalts were again erupted, and flooded an irregular topography cut into the sedimentary basin of proto - Lake Turkana, and are interbedded with lacustrine sediments and silicic tuffs. The sediments of the Kubi Algi and Koobi Fora Formations described by Vondra and Bowen (1976), and Behrensmeyer (1976), among others, overlie these volcanic rocks. A basalt with an age of about 2.2 m.y. has been reported from the northern part of this area.

On Nkalabong, volcanic rocks directly overlie the metamorphic basement. A single date from these rocks is 20 m.y., broadly comparable to the dates on the lavas of North Turkana. Here the volcanic rocks are mainly rhyolitic, although basalts also occur. The sediments of the Mursi Formation overlie these volcanic rocks in the southwestern part of the range, and this formation is itself overlain by lavas. One of these lavas has been dated twice yielding ages of 4.05 and 4.25 m.y. This lava is overlain by the Nkalabong Formation, which is only gently tilted, and contains a tuff dated at 3.95 m.y.

The rocks of Lorienetom and the Donyiro Hills and the Maji escarpment are poorly known, but the following information has been recorded. Lorienetom consists basically of rhyolitic rocks (Fuchs, 1939). The Maji escarpment consists dominantly of rhyolitic rocks overlying pre-Cambrian basement (Davidson *et al.*, 1973). The rocks of the Donyiro Hills are unknown. The distribution of rock types and major structural features is shown on figure 1.

2.1.2. Major structures

When one mentions East Africa, the structural feature which immediately leaps to mind is the East African Rift Valley, part of a major tectonic feature which extends from the Dead Sea in the north to Lake Malawi in the south. In the part of East Africa with which we are concerned, the East African Rift Valley is located in the southern and easternmost part of Lake Turkana, where it defines the boundaries of the lake. From there its path northward is obscure, and its topographic expression minimal, until Lake Stephanie (Chew Bahir) is reached in Ethiopia. The major faults related to the East African Rift Valley connecting these two areas are thought by Fitch and Vondra (1976) among others, to be located in a fault zone, designated the Kino Sogo Fault Zone, east of the central and northern parts of Lake Turkana. North of Lake Stephanie, the rift valley makes an abrupt jump to the east, and emerges as a distinct feature south of Lake Chamo from which it follows a well-defined course northward into the Afar depression. Impressive as this feature is, it plays at best a subsidiary role in the structural evolution of the Lower Omo Basin.

In the southern part of the Lower Omo Basin, the major structures parallel the major topographic features, and have an orientation which is more or less north-south. From east to west these are the fault system forming the western boundary of the Lake Stephanie graben, the major fault bounding the Labur Range on the east, the fault system which bounds the Lorienetom and Kacheriangorr Ranges on the east, and the fault which bounds the Lokwanamoru Range on the east. All of these faults are normal, and dip steeply to the east with the possible exception of the fault bounding the Labur Range. Walsh and Dodson (1969) present evidence to «suggest that [this] fault is a low angle thrust pitching southward at 20 to 25 degrees». On their cross section A-B (1966) however, they draw this fault as normal with a dip to the east. Here we prefer the interpretation presented on their cross section.

The origin of the basin must lie in time between ca. 12 m.y. (the youngest dates on the Turkana lavas) and about 4.5 m.y. (roughly the age of the basal sediments of the Mursi Formation). In the northern part of the Ethiopian Rift Meyer *et al.* (1975) point out that the Nazareth [volcanic] series is mainly restricted to a pre-existing rift structure. They note that it is possible that a first faulting event occurred in the same time as at the south-eastern escarpment of the Ethiopian Rift 5 or 9 million years ago. Thus it may be that creation of the Omo Basin as a depositional area is broadly coincident with the initial stages of formation of the main Ethiopian Rift. According to Meyer *et al.* (1975) the main faulting of the northern part of the Ethiopian Rift began about 1.6 to 1.8 m.y. ago.

The eastern margin of the basin is formed by a tilted surface developed on metamorphic rocks, with major movements probably occurring along the faults which bound the Labur Range and the Lorienetom Range. These faults are arranged in echelon fashion. The western margin of the basin is formed by the volcanic mass of Lorienetom, which was probably a major volcanic center, a good portion of which is now downfaulted and covered by younger alluvium, and which is presumed to have thinned to the east. The faults along the southern boundary of Nkalabong probably had their major offsets at about this time also, resulting in a trapezoidal area in which sediments were deposited by the Omo and Usno Rivers without evidence of tectonic disturbance for about 4 m.y. Vondra and Bowen (1976) believe that a major stream entered ancestral Lake Turkana south of the Kokoi horst which had its headwaters in the Ethiopian highlands, and which flowed through the region which is now occupied by Lake Stephanie. Thus it is possible that the faulting along the eastern margin of the Hammar Range also dates from this time.

From about 4.5 m.y. ago to about 0.8 m.y. ago, the sediments of the Mursi, Usno, and Shungura Formations were deposited in the vast depression formed by the preceding tectonic activity. The rocks on which these formations rest are nowhere seen. These formations consist of fluvial and lacustrine sediments, and are described in detail in an ensuing portion of this report. The Mursi Formation is capped by a lava flow (basalt) dated at about 4.2 m.y., and the Usno Formation contains a single basalt flow dated at about 3.3 m.y. Minor associated basaltic tuffs point to a nearby volcanic center for the Usno Flow. No lavas are known from the Shungura Formation.

In this region, Pleistocene to Recent volcanic rocks are rather limited in extent and have modified the physiography on only a local scale. Within Lake Turkana itself there are two young volcanoes in the northern and central parts. These are Central Island (basaltic), and North Island (trachytic). In the Lower Omo Basin the only volcanic feature which postdates the older Plio-Pleistocene formations is the Korath Range on the divide between Sanderson's Gulf and the modern course of the Omo River. The lavas of the Korath Range are basanites and tephrites of Upper Pleistocene age.

Farther to the east, there are young basaltic cones southwest of Lake Stephanie (Chew Bahir), and basaltic flows on the Bulal Plain (see Davidson *et al.*, 1973).

2.2. DEFINITIONS OF GROUPS AND FORMATIONS

A first approximation of the lithostratigraphic divisions of the Plio-Pleistocene formations of the Lower Omo Basin was proposed in 1970 (de Heinzelin *et al.*, 1970). It was completed and standardized in 1973 (Bonnefille *et al.*, 1973), and additional information on the stratigraphy was published in 1976 by de Heinzelin, Haesaerts, and Howell.

The formations of this part of East Africa are divided into two groups, the Omo Group (Pliocene to Lower Pleistocene) and the Lake Turkana Group (Upper Pleistocene to Recent). The two groups are separated by a disconformity and a time gap of about 700,000 years.

Following Berggren (1974), we provisionally accept the Pliocene/Pleistocene boundary as occurring at about 1.65 m.y., that is, near or at the end of the Olduvai Normal Event in the Matuyama Reversed Epoch of the polarity time scale. We accept the base of the Brunhes Normal Polarity Epoch as the boundary between the Lower and Middle Pleistocene, near the onset of the Cromerian, around 700,000 years ago. The boundary between the Middle and Upper Pleistocene is usually defined as the onset of the Last Interglacial Eemian, around 130,000 B.P. (Bandy, 1972; Butzer, 1974; Cooke, 1973), and we follow that definition here.

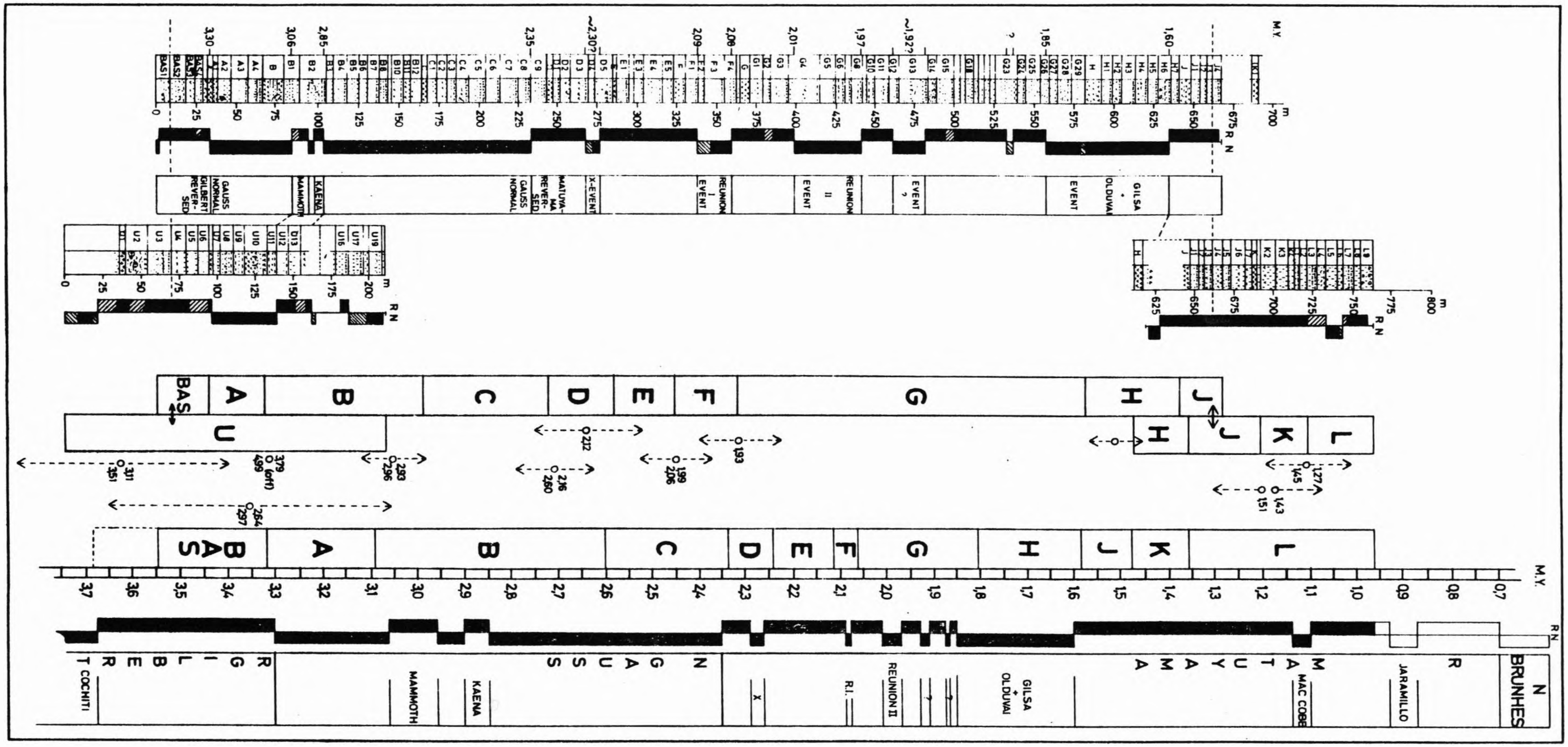

Fig. 2.- Thickness and chronology of the Shungura and Usno Formations.

2.2.1. The Omo Group

Six formations exposed in the Lower Omo Valley are placed in this group. Three of these are of different ages - the Mursi, Nkalabong, and Shungura Formations. The Usno Formation is correlated with the lower part of the Shungura Formation (Basal Member to Member B). Two others, the Loruth Kaado and Nayena Epul beds are uncorrelated with the other four. All of these formations are tilted (usually to the west) and faulted.

Mursi Formation : This formation crops out at Yellow Sands at the southwestern tip of the Nkalabong Range. It is over 140 m thick and is over 4 m.y. in age (Brown and Lajoie, 1970; Fitch and Miller, 1976). It contains both vertebrate and molluscan fossils and is described in detail in a later section of this report.

Nkalabong Formation : This formation crops out to the west of the Mursi Formation at the southwestern tip of the Nkalabong Range. It is about 90 m thick, and Fitch and Miller (1969) report an age of 3.95 m.y. for a tuff from the middle part of this formation. No fossils have been reported from this formation, and it was not examined by us. It is not further discussed in this report.

Usno Formation : The exposures of this formation are a serie of small patches on the western side of the Omo River south of its confluence with the Usno River. Because of its geographic isolation it is still considered as a separate formation although it is now securely correlated with the lower part of the Shungura Formation. It is over 172 m thick and ranges in age from about 3.6 m.y. to about 2.7 m.y.

Details on the stratigraphy and correlation of this formation are given in a later section of this report. These data are presented on the generalized diagram fig. 2.

Shungura Formation : The outcrops of this formation form a narrow N-S trending belt 60 km long to the west of the lowermost Omo Valley (broadly speaking called Type area) and of the Omo delta plain (broadly speaking called Kalam area). Both areas have been correlated together, the total thickness being over 766 m.

The Type area in the first and principal instance and also the Kalam area subsequently have yielded a vast assemblage of vertebrate fossils (40,000 in number) and invertebrate fossils (principally ostracodes and molluscs). On the basis of potassium-argon ages on intercalated tuffs and the paleomagnetic record of the sediments, its age is estimated as spanning the time range from about 3.55 m.y. to 0.95 m.y. or perhaps 0.8 m.y. (depending on two possible paleomagnetic correlations).

Details of the stratigraphy and correlation of this formation are given in a later section of this report. We present already its total thickness on the generalized diagram fig. 2.

From left to right, the following data are graphically compared :

- Thickness of the Shungura Formation in the Type area, simplified presentation of the sedimentary units, integrated paleomagnetic readings according to F. Brown.

- Below, similar data for the Usno Formation; above, complementary data from the Kalam area for the uppermost accessible sequence.

- Sequence of Members and potassium-argon datations according to F. Brown. Horizontal arrows indicate the correlation horizons between Shungura and Usno Formations and between Type area and Kalam area.

- Tentative setting of Members in absolute time-scale taking radiometric and paleomagnetic data into account. A correlation between the normal event in Member L and the Mac Cobb Mountain event is suggested in this chart (Mankinen, Donnelly and Grommé, 1978). A possible correlation with Jaramillo would imply a long time-gap, which is not materially documented, in Lower Member L.

Loruth Kaado and Nayena Epul beds : These beds hardly deserve formational names. They occur in two limited areas of exposure at the north end of the Labur Range, west of Sanderson's Gulf. The Loruth Kaado sediments contain fossil wood, molluscs and sparse vertebrates. Casts of mollusc shells are known from the Nayena Epul beds. These beds have not been correlated with the other formations in the Lower Omo Basin, and are not further described in this report.

Original definitions of the first four formations discussed above are found in Butzer (1969), de Heinzelin and Brown (1969), and Brown, de Heinzelin and Howell (1970).

2.2.2. The Turkana Group

Although not studied in this monograph, there are Middle to Upper Pleistocene and Holocene formations in the Lower Omo Basin. We suggest that they be assembled into a group named the Lake Turkana Group.

Bume Formation : The Bume Formation occurs in only two outcrops, P336 and O19, between the exposures of the Shungura Formation and the present course of the Omo River in Sectors 16 and 18. It is made up of lacustrine deposits which differ in facies and shelly fauna (molluscs and ostracodes) from the deposits of the Shungura Formation. It is bracketed in time between the uppermost Shungura Formation and the lower Kibish Formation, and is thus most likely of Middle to Upper Pleistocene age. Previously these beds were designated the Bourillé Formation, but this name must be dropped as the site of Bourillé of C. Arambourg (1933) is too distant from the outcrops. It is here renamed the Bume Formation, the name being derived from the site of Bume on map 4-1 of Butzer (1971) as there is no local name.

With respect to the Shungura Formation, two points should be stressed. First, the Bume Formation is quite independent of the Shungura Formation on faunal grounds. Earlier a correlation with the upper part of the Shungura Formation had been anticipated, but this is no longer tenable. Second, Roger (1943) reports molluscs of the Bume Formation, molluscs of only this formation as «Formations lacustres anciennes». The locality mentioned by him as being «6 km au Nord de Bourillé», or «piste de Karo» (fig. 1) is O19 of this report. C. Arambourg did not collect any shelly fauna from the Shungura Formation itself in 1933.

Kibish Formation : This formation is composed of lacustrine and deltaic sediments of Upper Pleistocene to Middle Holocene age wich lie discordantly on the Omo Group. Near Kibish it overlies the Nkalabong and Mursi Formations, and farther south it occurs as a thin veneer of sediments overlying the Usno and Shungura Formations (Butzer, 1969). As discussed above, it is slightly disturbed by faulting, for example in the Shungura Formation Type area, Sector 1.

Errum Formation : A group of lacustrine sediments, beach features, gravels, reddish sediments and a tuff lying discordantly on the Shungura Formation in the Kalam area are defined as the Errum Formation in this monograph. It may be a lateral extension of the Kibish Formation, but this has not yet been demonstrated. The thickness of this formation is less than 10 m, and it is probably of Upper Pleistocene age.

Lobuni beds or *Narok beds* : These beds include young and modern features of the Omo delta, contemporary flood plains of the Omo River, and beaches of Sanderson's Gulf and Lake Turkana according to Butzer (1969 and 1970, 1971, respectively).

2.2.3. Paleohydrography

There are no known outcrops of Plio-Pleistocene formations east of the Lower Omo-Usno course. We think indeed that the Hammar Range was already uplifted in Pliocene times.

The observed extension of Plio-Pleistocene formations of the Omo Group reaches 110 km in N-S direction. There is a large gap due to the more recent cover of the Kibish Formation between the northern sectors of the Shungura Type area and the Mursi Formation at Yellow Sands.

Outcrops of what was presumed to be the Shungura Formation were noted about 1 km northeast of the northern end of the Korath Range by one of us (FHB). Here the beds dip about 10° to the West. About 5 m of section are exposed, including a bluish gray tuff. The tuff is underlain by sand and overlain by silt. The sand is fossiliferous and the fossilization is similar to that of fossils from the Shungura and Usno Formations. These outcrops are important only in extending the known western limit of the Shungura Formation near the northern end of its outcrop.

West of the Korath Range, near Natodoremi, Butzer (1976) collected a molar of *Elephas iolensis*, which is extremely hypsodont, and presumably younger than the elephants of Member L. The deposits from which it was derived may be intermediate in age between those of the uppermost Shungura Formation and those of the lowermost Kibish Formation. Similar sediments may be exposed along the Kibish River near Kibish. These sediments are important in that they may reflect deposition of the detritus carried by the Omo River in a new area, west of the area in which the Shungura Formation was deposited, and this in turn may have a structural or tectonic cause.

Questions have been raised about a possible link between the Lake Turkana Basin and the Nile drainage. Butzer (1971) suggests that in Early Holocene times connections with the Pibor-Sobat River system were real but tenuous. In Pliocene and Lower Pleistocene times broader connections of longer duration may have existed, but these have not been substantiated by geologic evidence at the present time. The fauna from Pliocene and Lower Pleistocene formations seems to be related to that of the Western Rift and of the Nile drainage basin. Findlater (1976) has outlined a history of the Lake Turkana basin in which he discusses times when the lake had an open drainage, and times when the basin was closed. The present isolation of Lake Turkana and the highly alkaline nature of its water may be a later feature subsequent to the faulting which affected the Shungura Formation in Middle Pleistocene time (Carbonel and Peypouquet, 1979; Peypouquet, Carbonel and de Heinzelin, 1979).

2.3. DEFORMATION AND FAULTING (F.H. B.)

2.3.1. **Deformation of the Omo Group**

a.- Ilgwa-Naito block

The exposures of the Shungura Formation occur in two non-contiguous elongate areas, informally designated the Type area (northern) and the Kalam area (southern). There is a thin mantle of surface cover between these two areas of exposure. While this division is useful geographically, it is more convenient to discuss the structure in terms of two blocks which are here referred to as the Errum-Shungura Block and the Ilgwa-Naito Block. The division between these two blocks is placed at a fault which lies just north of Ilgwa, and to the west of Kalam. The structural patterns in these blocks are distinct, and there is a discordance in strike of the beds in the blocks of about 40°.

The total amount of section exposed in the Ilgwa-Naito Block is small, comprising only part of Member L, Member K, at least the upper part of Member J, perhaps the lower part of Member J and perhaps the upper part of Member H - at most about 125 meters of section. The block is bounded on the north and east by faults or alluvium, and on the west by alluvium, although a fault may be present along the western side as well. There is really no southern margin to the block as the eastern and western boundaries converge at Namuruputh. The relief is low, perhaps 20 meters, and exposures are generally poor. The strata dip to the west at about 10°, and are broken by a number of anastomosing faults which generally trend in a north-south direction. Displacement on these faults is small (ca 30-40 m), and in most cases the eastern block is displaced downward. The faults in this block are assumed to be normal, and it may be that some of these faults converge at depth. The exceptions to downward throw on the east lie in the eastern bounding fault, and a fault which parallels it at its southern end. The Ilgwa-Naito block as a whole is downthrown to the west, and the fault along which this occurs is assumed to be normal, because it has enough topographic expression to indicate that it dips to the west at a rather high angle. The faults which dip eastward and have only minor displacements may simply be small anthithetic faults related to the major fault on the east. In the southern part of the block both the beds and the faults describe a broad arc concave to the west, a condition for which we offer no explanation.

A portion of the aerial photograph on which the boundary between the two major blocks appears is shown in figure 3. A structural interpretation of the features on this photograph is given in the next diagram. The most important feature on the photograph is the presence of a photolineament, interpreted as a fault, flanked by arcuate patterns, which, in stereographic observation, are seen to be minor folds. The sense of motion on this fault is taken to be right lateral because of the sense of the minor folds. It is thought that at least part of the discordance in strike between the Ilgwa-Naito and Errum-Shungura Blocks is explained by rotation of the blocks relative to one another along this fault. A more tenuous supposition is that the eastern bounding fault of the Naito Block is offset by this lateral fault. If this is the case, then the Ilgwa fault developed later than the fault which bounds the Ilgwa-Naito Block on the east.

b.- Errum-Shungura Block

In this block the essential structure may be described as a faulted homoclinally dipping sequence of beds which change gradually in strike from about N 20° E to about N-S as a single bed is followed from south to north. The beds dip to the west at about 10°. In the southern part of this block the structure is simple, and the beds are cut by only a few faults which trend northeast, and along which movement is relatively small. The northern part of the area is intricately faulted, as can been seen on figure 1. There is also a minor amount of folding in the Type area which is thought to be related to the faulting. The exposures in the Errum-Shungura Block are bounded on all sides by younger alluvium.

Near the eastern margin of the southern part of this block there is a fault along which about 550 m of offset has taken place, and upper Member L is in contact with lower Member C. Unfortunately this fault is not exposed to the north, but it may be an extension of the midline fault in the Shungura Formation exposed in the Type area.

Most of the faults in the Shungura Type area trend N-S or nearly so. They are not planar, but curviplanar in general. Where exposed these faults dip 60° to 70° to the east, and in most cases the eastern block is downdropped.

The structure can be viewed most simply in terms of three major faults, one exposed for only a short distance in the northernmost part of the exposures where Member B is faulted against Member G. The second is a fault which traces out a sinuous course through the Type area of the Shungura Formation, and from which many splay faults arise. The third lies along the eastern edge of the exposures in the northern part of the Type area. The displacement on these faults is variable along the trace of the fault, but is roughly 150 to 400 m along the western fault, 250-300 m along the midline fault, and 300 m along the eastern fault. The total accumulated offset on any east-west section is about 700 m.

Folds occur, but are only minor features of the structure. Perhaps all of these may be regarded as features related to the faulting. At the north end of the exposures there is a badly faulted anticlinal structure. In order to explain this as a drag feature, an additional fault must be postulated east of the outcrop area. Minor folding occurs along the midline fault, especially where it crosses the lacustrine deposits of upper Member G, in fact the large exposure of Member G at the north end of the outcrop area is a broad shallow synclinal feature. A third area of folding exists where the Shungura Formation most closely

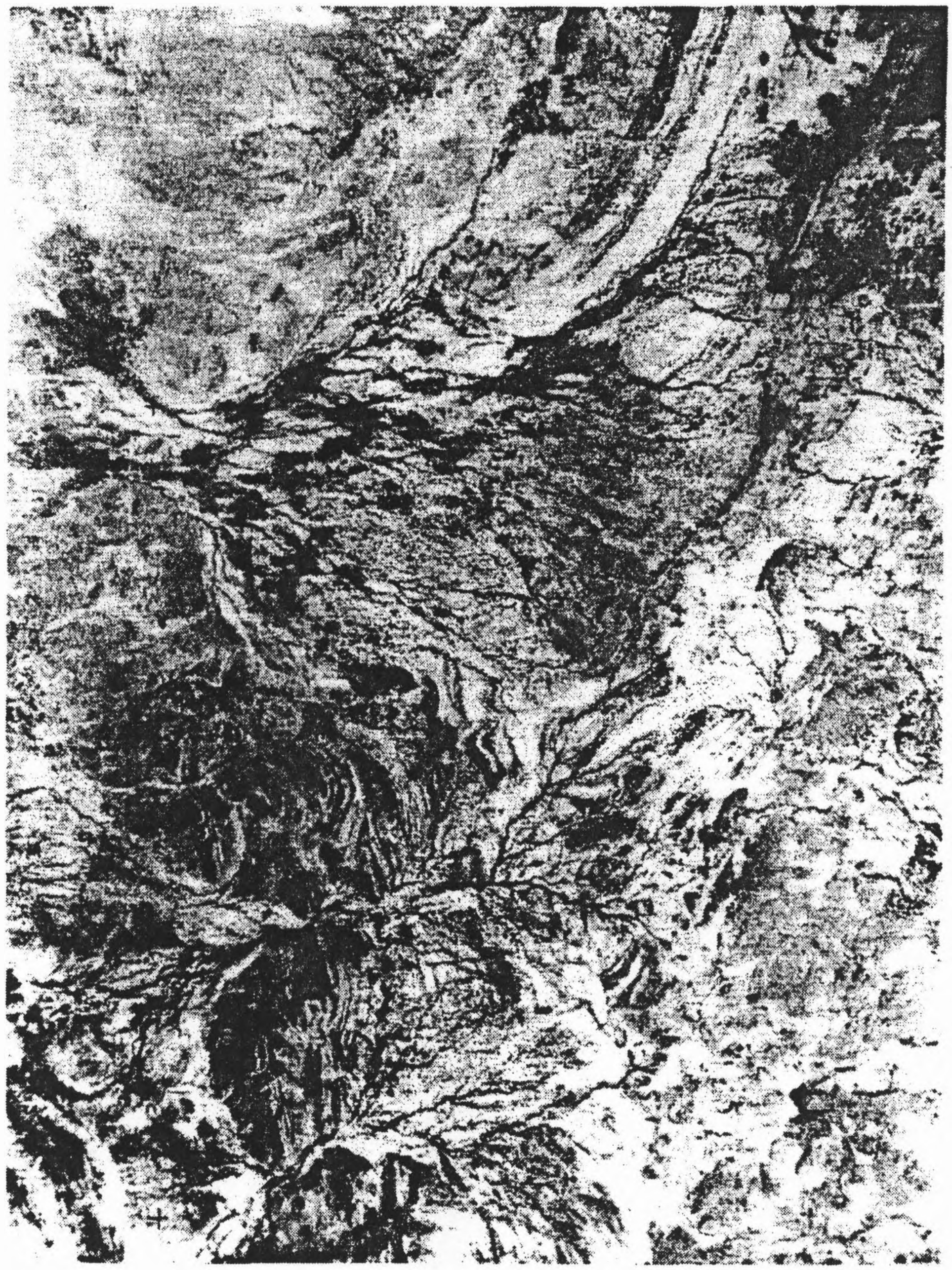

Fig. 3.- Air picture

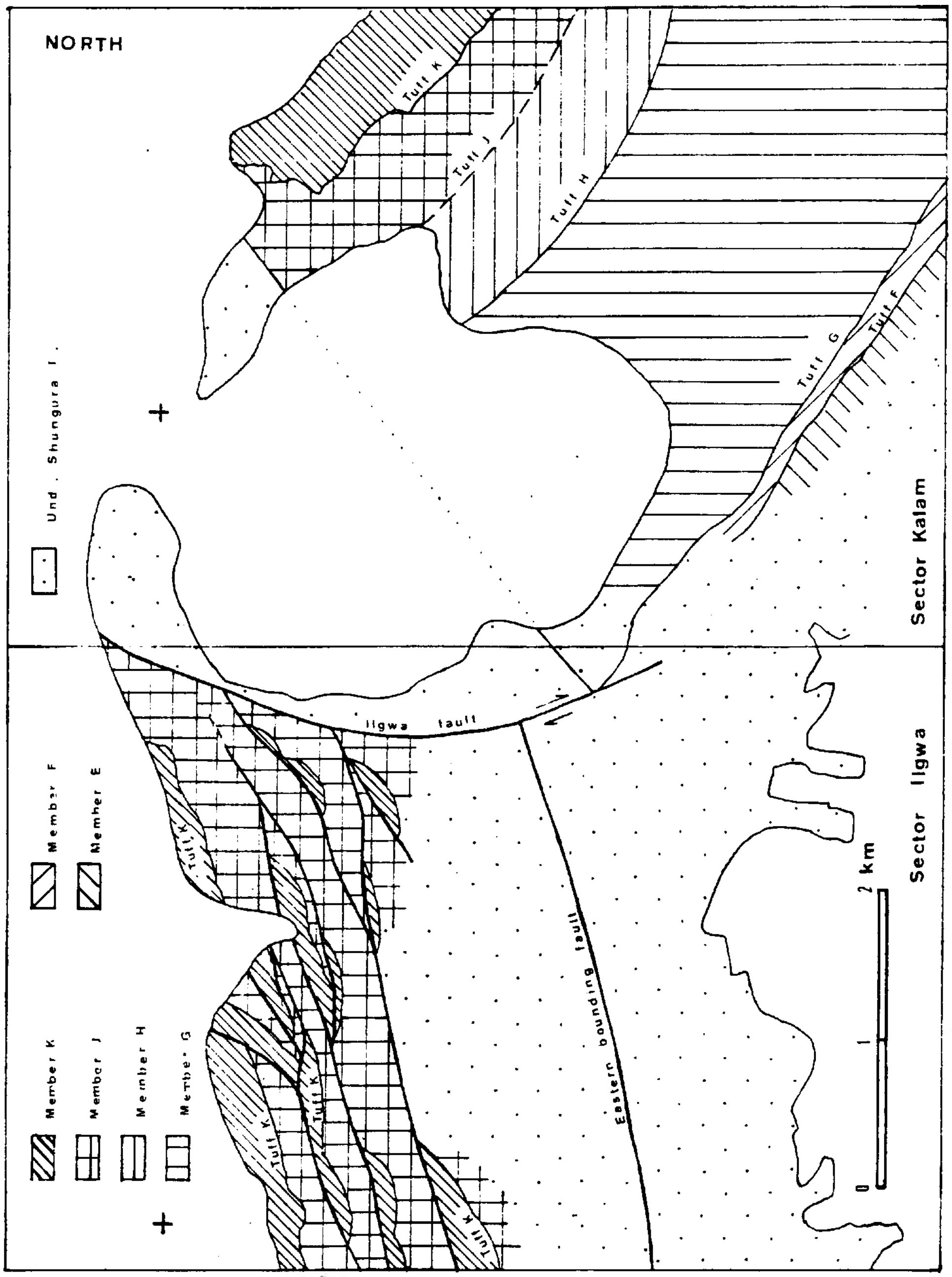

Fig. 3.- Fault contact between Errum-Shungura block to the north and the Ilgwa-Naito block to the south.

approaches the Omo River. Here a faulted anticlinal structure is found, which again necessitates postulation of a fault along the river.

All of the faults described above may be related to a major fracture which is assumed to lie near the western margin of the floodplain of the Omo River. It is supposed that this fracture involves basement rocks of greater competence than the overlying sediments, and that the eastern block is again downdropped. It should be noted that some such structural feature is necessary to explain the absence of the Shungura Formation from the east side of the Omo River. If this is the case, then the faults which break up the Shungura Formation can be viewed as synthetic faults along the eastern bounding fault of a horst developed just west of the present course of the Omo River.

It should also mentioned that evidence for intraformational faulting in the Shungura Formation is confined to the Basal Member. Intraformational faulting is also noted in the lowest part of the Usno Formation which is correlated with the Basal Member of the Shungura Formation.

c.- Usno Formation

The Usno Formation is exposed along the west side of the Omo River about 30 km north of the northern limit of the exposures of the Shungura Formation. It has been correlated with the Basal Member and Members A and B of the Shungura Formation. The structure is relatively simple. The beds of the Usno Formation strike about N 25° E and dip 10 to 14 degrees to the west. They are cut by a number of faults which strike along the direction of the beds themselves, and have created a number of small horsts and grabens. The entire formation, like the Shungura Formation, is confined to the western side of the Omo river, and again a fault near the western margin of the floodplain is thought to explain this. A displacement of about 250 m is necessary on this supposed fault. Evidence for such a fault is provided by the large metamorphic block found along the escarpment at the eastern margin of the Usno Formation, and by the fact that a large area of hot springs and geyser pools occurs at this boundary as well.

d.- Mursi Formation

The Mursi Formation, located on the western side of the southwestern end of the Nkalabong Range, is roughly 130 m thick at Yellow Sands, and was tilted and faulted after deposition. The interpretation of the structure of the Mursi Formation presented by Butzer (1976) differs markedly from that derived from observations made by one of us (J. de H.) in 1973. In the earlier interpretation, Butzer described a number of faults, one involving the Kibish Formation with a displacement of 58 m. The overlying Nkalabong Formation (nearly the same age as Mursi) is said to be undeformed. In fairness it should stated that most of the faults described by Butzer have displacements of 1 to 10 m. de Heinzelin observed only small faults along a profile drawn across Yellow Sands. Whereas Butzer described a series of small horst-graben features along the eastern edge of the outcrop, these were not noted by de Heinzelin. All of the faults encoutered by de Heinzelin were normal with the eastern side downdropped. Maximum displacements are on the order of two meters.

There is evidence of intraformational faulting to a minor extent.

The points to be noted about deformation of the Mursi Formation are that again the faults are roughly coincident with the strike of the beds, suggesting that the two features are causatively related. Secondly, the Mursi Formation is tilted to the west, as are the Usno and Shungura Formations, and blocks are downdropped to the east. These faults trend about N 50° E and have the same sense of displacement as the major fault bounding the Nkalabong Range on the southeast. It may be that these faults record a second period of movement on the major fault bounding Nkalabong.

2.3.2. **Deformation of the Turkana Group**

a.- Bume Formation

The age and former extension of the Bume Formation is still a debatable point, of much concern for the dating of the major faulting episode(s) in the Lower Omo Basin.

At the two and only outcrops where they occur, the beds of the Bume Formation seem to have suffered the same amount of deformation as those of the Shungura Formation. In both instances, the contact is a sharp, curvilinear fault.

Nevertheless, there must be a long time gap between both depositions, as indicated by marked differences in the invertebrate faunas, molluscs and ostracodes.

Does it mean that the main structural disturbances are later than the Bume Formation and all date from the Upper Pleistocene or that there have been several phases resulting in similar patterns; the second answer is more likely true but cannot be fully demonstrated yet.

b.- Kibish Formation

The Kibish Formation, which ranges in age from about 5000 to perhaps 100,000 years was often stated to be undeformed. We wish here to remove the misconception that the Kibish Formation is undeformed; a better statement is that it is only slightly deformed. Faults have been observed cutting the Kibish Formation at the northern end of the main exposures of the Shungura Formation, and along the Omo River where it flows from west to east as it rounds the end of the Nkalabong Range. A third area may be present on the eastern margin of the Mursi Formation exposures described by Butzer (1976). Finally it appears from an examination of the aerial photographs that a long beach ridge running WNW to ESE between the northern end of the Shungura Formation exposures and the Usno Formation exposures is faulted and downdropped about 10 m on its eastern end.

2.4. STRUCTURAL EVOLUTION

All of the formations discussed above are interpreted as having been deposited in either fluvial or lacustrine environments. The Mursi Formation, about 4.5 m.y. old at the base, records the oldest sediments in the basin, thus placing a minimal age on the time of formation of the basin. The Usno Formation records coarse alluvium derived from the metamorphic rocks of the Hammar Mountains in its lower part, and a mixture of volcanic and metamorphic detritus in its upper parts, presumably reflecting, in order, the rapid removal of weathered metamorphic material from the newly uplifted Hammar Range, and subsequent diminution of this material with greater admixture of material from the Omo and Usno Rivers which drain volcanic terranes. The same sort of metamorphic detritus, in lesser amounts is also found in the lower parts of the Shungura Formation. Of far greater significance, however, is the fact that from about 3.5 m.y. ago to about 1.9 m.y. ago, the Shungura Formation is made up dominantly of fluvial deposits, with evidence of backswamps, meanders, and so forth. The continuity of lithologic units, particularly tuffs, is marvelous, and indicates that the river was depositing its load on a plain of very low gradient. Lacustrine beds are rare in this time interval, and therefore we must visualize deposition in a sinking area in which subsidence was nearly equal to the amount of deposition. Were this not the case, we would expect to see periodic lacustrine incursions in the fluvial sediments. Some idea of the position of the center of the subsiding region may be gained by considering the difference in depositional rate between the Type area and the Kalam area.

Cumulative thicknesses of sedimentary units are compared on two diagrams in fig. 4. On the first diagram two parts of the Shungura Formation from Upper Member C to Tuff K are compared between the Type area and the Kalam area. On the second diagram, the Usno Formation is compared to the Type area of the Shungura Formation, from the Basal Member to Middle Member B. The latter diagram shows an almost complete parallelism in the rates of sedimentation; we conclude that this part of the basin was stable or affected by the same amount of subsidence during deposition.

A different situation is found later in time between the Type area and the Kalam area. Unequal rates of subsidence must be accepted, as all beds are surficial, shallow-water, or nearshore deposits. From Middle Member D upwards, the Kalam area subsided at a slower pace than the Type area, except in G-15 to G-20, and in Member J. Even in the southern part of the Shungura Type area (Sectors 24 and 26), a notable disconformity separates G-28, G-29, and Tuff H from the underlying units.

As we have seen, thicknesses are relatively constant for any lithologic unit from north to south in a large part of the Type area; in the Kalam area, the deposits are thinner and the ratio of thickness from one area to the other is nearly constant for all members. A subsiding trough situated along the present axis of Lake Turkana would explain the observed thickness differences between the Kalam area and the Type area nicely. The Kalam area, located on the western margin of such a trough would always be situated slightly higher than the Type area, and beds would be expected to thin in that direction.

The large lacustrine incursion which occurs between about 1.9 and 1.85 m.y. ago in Upper Member G is also of structural significance. This sequence is about 150 m thick and is bounded both below and above by fluvial sediments. If this incursion is regarded as being of climatic origin, then we would expect to see channels cut into the lacustrine sediments when the ensuing fluvial deposits were laid down. This is not the case. There is no evidence that the lacustrine sediments were dissected following their deposition. Instead we see

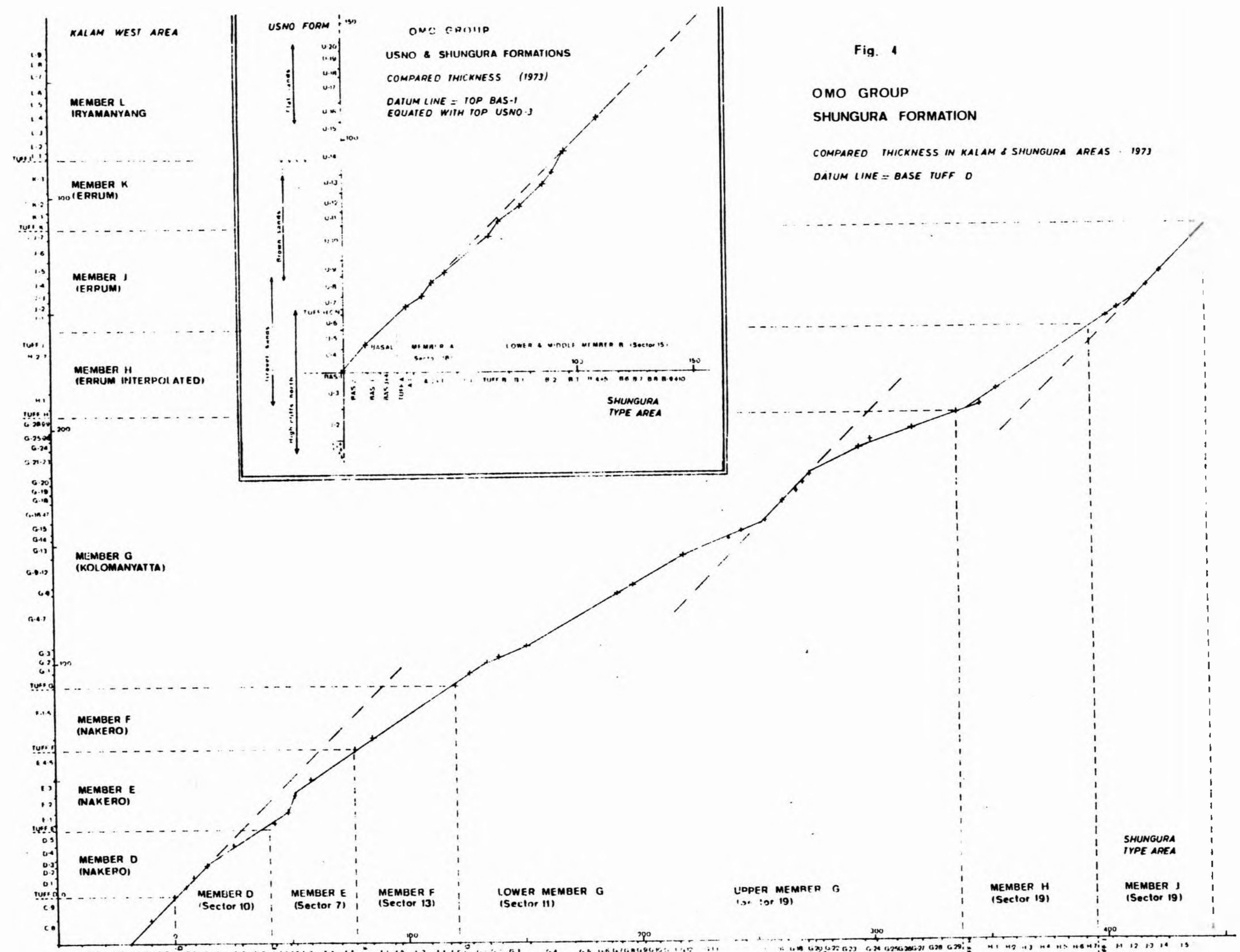

Fig. 4.- Compared thickness of the Shungura Formation in Kalam and in Shungura areas - Compared thickness of the Usno and Shungura Formations.