



COLONY AND PROTECTORATE OF KENYA

MINISTRY OF COMMERCE AND INDUSTRY
GEOLOGICAL SURVEY OF KENYA

**GEOLOGY OF THE
MANDERA-DAMASSA AREA**

DEGREE SHEETS 8, S.W. QUARTER, 16 AND 24, N.W. QUARTER
(with three coloured geological maps)

by

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FOREWORD

The publication of the report on the Mandera-Damassa area completes the presentation of works on the more important part of the Mesozoic basin that occupies the north-east corner of Kenya. The part of the basin west of the area now dealt with was described in Reports Nos. 43 (Derkali-Melka Murri area) and 40 (Takabba-Wergudud area), and the part to the south-west in Reports Nos. 44 (El Wak-Aus Mandula area) and 47 (Bur Mayo-Tarbaj area).

The Mandera-Damassa area is entirely occupied by sediments of middle Jurassic or later age, and is notable for the presence of several fossiliferous beds that enable the rocks to be dated geologically with reasonable soundness. The sediments in the most north-eastern part of the area have suffered considerable vicissitudes in their dating. For some time they were considered as lower Jurassic by comparison with some beds not far away in Somalia, then they were regarded as lateral equivalents of the sandstones and other sediments that form the Marehan hills, and probably Cretaceous in age. Palaeontological work later led to the idea that the sediments around Mandera were middle Jurassic, though doubt was soon thrown on the dating of the fossils. Mr. Joubert's mapping, in conjunction with what is now known of the fossil assemblages, proves conclusively that the Mandera Series is, in fact, the uppermost part of the upper Jurassic of north-east Kenya and that it is, like the Jurassic sediments of earlier date, overlain unconformably by the Cretaceous sediments that form the hills of the area.

The report includes a map and account of an anticlinal horst at the Hegalu hills, on the Somalia border. The recognition of the Jurassic and Cretaceous sediments on and around the horst has allowed the estimation of the throw along the bounding faults as 1,500 feet or more, and has given proof that in early Cretaceous times the horst stood up as an island, but was later buried by the Cretaceous sediments.

The possibility of the occurrence of oil in the area is discussed, and the conclusion reached that several geological features are attractive from that view-point. The most important mineral in the area at present is, however, water, and the author makes numerous suggestions on how the supply could be improved.

The work connected with the report was carried out with the assistance of Colonia Development and Welfare Vote funds.

Nairobi,
1st March, 1957.

WILLIAM PULFREY,
Chief Geologist.

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ABSTRACT

The report describes an area of some 2,650 square miles occupying the extreme north-eastern corner of Kenya. The area, which is triangular in shape, is bounded by longitude 41°E. in the west, by the Kenya-Somalia border in the east, and by the Daua river on the north, where this river forms the boundary between Ethiopia and Kenya.

Topographically the area consists largely of the end-Tertiary peneplain which has been dissected in the north by the Daua river and its tributaries since early Pleistocene times and where erosion surfaces and terraces record the pluvial phases of the Pleistocene. From the end-Tertiary erosion surface rise several hill ranges, all bevelled by two earlier periods of peneplanation.

During Jurassic times a series of limestones and shales, the Daua Limestone Series was deposited in a neritic environment in a gulf extending over what is now the north-eastern part of Kenya. Towards the close of the Jurassic a regression of the sea occurred, leaving a variety of sediments that comprise the Mandera Series in its wake. The Jurassic sediments were unconformably overlain by sediments of the Marehan Series when another marine transgression took place during Lower Cretaceous times and was superseded by an estuarine phase which eventually gave way to terrestrial sedimentation. Younger rocks, probably of Pleistocene age, as well as Recent crustal, fluvial and residual deposits mask the older deposits in parts of the area. An account is given of the various rocks and an attempt is made to correlate them with contemporary deposits along the eastern margin of Africa.

The prospects of finding oil in the sediments are discussed.

GEOLOGY OF THE MANDERA—DAMASSA AREA

I—INTRODUCTION

The area described in this report is approximately 2,650 square miles in extent and is bounded by the Kenya-Somalia border on the east, by the Kenya-Ethiopia border on the north which is the course of the Daua river, and by longitude 41°E. on the west. It includes the parts of Kenya that fall within degree sheets Nos. 8, 16 and 24 (Kenya) (sheet Nos. 21, 22 and 36 of the Directorate of Colonial Surveys). The area is part of the Mandera Administrative District of the Northern Province and is a closed district under the Outlying Districts Ordinance (Proclamations Nos. 89 of 1925 and 35 of 1926).

The area was mapped between January and October, 1954, with a break in field-work of about five months in the middle of the period. P. V. Caswell shared the work of the first field period, which terminated on the call-up of the geologists for Emergency duties, and was not able to return when the writer was released to resume field-work.

Apart from the smaller tribes occupying small portions in the vicinity of the Daua river, the area is mainly inhabited by Somali tribesmen known as the Murille, Dugudia and Garri, between whom the grazing rights are divided. For most part of the year the population is found either along the stretch of country near the Daua river or centered on the wells of El Wak, near to the southern extremity of the area, where camels, goats, sheep and cattle can be watered. The young men, whose diet is almost exclusively camel's milk, seek good pasture for the camels in the interior of the area and return for water once every three weeks. During and for a time after the rainy seasons, when water can be found in depressions and rocky pools in the vicinity of the hills, the population is sparsely scattered over the whole of the area.

The motorable roads in the area are usually in a poor state of repair, owing to lack of funds for their upkeep. Mandera is reached from El Wak by a road that follows the international boundary to Bur Mansa where it leaves the border and skirts the Hegalu hills. The road from Mandera to Melka Murri runs along the Daua valley roughly parallel to the Ethiopian border through Rahmu, where a road branches off to the south. Eleven miles along the latter road, a branch to Moyale turns off to the west while the road continues south to El Wak, crossing longitude 41°E. to the north-west of the Bamba hills. Many large camel tracks cross the area, and several were most useful in traversing and mapping. Mandera is in touch with Isiolo and Nairobi by radio communication, and the police keep in touch with the outposts by the same means.

Maps.—For convenience in printing the geology of the area has been drawn on two sheets, the Mandera sheet and the Damassa sheet. In descriptions that follow, however, the area will be treated as a whole. The geological maps are based on aerial photographs, the scale of which is approximately 1:30,000. One astronomically determined point, the Kenya-Somalia boundary cut, and the following preliminary plots of the Directorate of Colonial Surveys, published in 1950, were used as ground control:—

North A 37 Sheets FI NW (21/I)
FI NE (21/II)
FI SE (21/IV)
FII NW (22/I)
FII NE (22/II)
FII SW (22/III)

North B 37 Sheet X III SW.

The form-lines on the maps are based on numerous barometer readings but are approximate only. Where form-lines would have interfered with the geological information on the maps they have been omitted, as the numerous geological horizons give expression to the topography. Elevations recorded on the maps are based on the work of the Jubaland Boundary Commission along the Kenya-Somalia border, but, although the Commission took diurnal variations into consideration (King, 1928, p. 433)*, fairly frequent alterations were found to be necessary during the present survey.

*References are quoted on pp. 58-59

Climate and Vegetation.—Rainfall over the area is low as is shown by the following figures:—

STATION	Altitude in feet	Total 1951 (inches)	Total 1952 (inches)	Total 1953 (inches)	Total 1954 (inches)	Annual average (inches)	Years recorded
Mandera District Office	1,085	16.75	3.92	7.05	8.27	8.15	13
El Wak	1,200	13.10	13.21	12.54	10.32	11.33	4
Melka Murri	3,300	6.24	5.21	15.48	6.39	9.13	4
El Roba	3,300	—	5.30	14.92	7.77	9.67	3

El Wak is just west of the southern extremity of the area while Melka Murri and El Roba lie north-west of the northern part of the area. The figures indicate a higher rainfall over the higher ground to the west of the area, while the figures for 1951 reflect the high rainfall prevalent over Kenya as a whole during that year. The maximum rainfall occurs during April and May, though the main rains sometimes start about the middle of March; localised showers fall during the months of October and November. During the rains no vehicular traffic is allowed through the area in order to conserve and protect the surfaces of the roads.

The limestone and shale country of the Jurassic outcrop is covered, often scantily, by an open thorny scrub with large trees along some of the larger dry river-courses, a vegetation pattern that is distinct from the thorn-bush and trees supported by the sandy soils derived from the Marehan Series. The latter vegetation is sometimes unpleasantly dense along gullies but small grass-covered glades are encountered in the southern part of the area, and often surround "pans" where water accumulates during the rains. During the dry seasons the monotony of the seemingly dead brushwood is relieved by the fringe of doum palms along the course of the Daua river.

Acknowledgements.—The writer wishes to thank Drs. Muir-Wood, Cox, Spath and Franks of the British Museum and Dr. Arkell of Cambridge University for the identification and dating of the fossils collected during the survey. Assistance given in the field by the Police of the Mandera Division is also greatly appreciated.

II—PREVIOUS GEOLOGICAL WORK

An Italian expedition led by M. Sacchi crossed the Daua river at Neboi in 1895 and, skirting the valley, crossed the area to the west. In 1900 the results of the expedition were published by Angelis d'Ossat and Millosewicz together with the first geological map of the area. On this map the whole of the stretch along the Daua river is shown to consist of "Formazione gessifera; Lugh (Gypskeuper)" with an outcrop of the underlying "Arenarie mesozoiche con scarsi fossili marini: Lugh (Lettenkohle)" at Malca Duca (Melka Dakacha) and a capping of "Conglomerati di diversa epoca" to the south of Melka Dakacha. "Calcari marini mesozoici (Guirassico)" are shown north of the Daua at Maddo Errelle (Muddo Erri) and according to the description, overlie the Lugh Beds.

In a description of the country and inhabitants between the Juba river and Lake Rudolf, Aylmer (1911) mentioned the "Wells of God" of El Wak. He wrote "The water is found underground in a sort of light bluish clay, and is said never to have been known to show signs of decreasing in quantity. In the neighbourhood is coral limestone, gypsum and other deposits probably similar to the geological formation in Northern Somaliland".

Parkinson (1917 and 1920) described the Jubaland Series exposed along the Juba river as consisting typically of blue shales or mudstones and associated reddish sandstones. Fossils collected from the shales indicate an Upper Oxfordian age. A description of the unfossiliferous calcareous and gypsiferous deposits of El Wak was also given.

A short account of the sedimentary series of north-eastern Kenya was given by Glenday (1929) who was the first to describe the fossiliferous section of the Daua Limestone Series occurring at Muddo Erri. The collection of fossils from the Jurassic rocks was presented by Glenday to the Hunterian Museum at Glasgow University and was described by Weir, Currie and Latham (1929). A more detailed description of the geological succession compiled from the field notes of Glenday, was included in this work. The designation "Daua Limestone" was used for the beds up to the base of the Mandera Series but the Mandera and Marehan Series were included together as the Marehan sandstones, and it was recognised that the sandstones overlie the Jurassic sediments.

Dejean (1937) reported the discovery of alleged petroliferous sand along the western slopes of the Willeh hills. In the same year the area was examined by H. G. Busk and J. P. de Verteuil on behalf of the D'Arcy Exploration Co. Ltd. and the Anglo Saxon Petroleum Co. Ltd.

In a novel interpretation of the geology of the sediments, Busk reversed the stratigraphical succession and postulated that the hills composed of Marehan sandstone were fault blocks which had been islands in the Jurassic sea and around which the Jurassic calcareous sediments had been deposited (Busk and de Verteuil, 1938, Busk, 1939). The Mandera Series was taken as part of the Marehan Series, while the limestones of the Mandera Series were apparently confused with the Daua Limestone Series. In addition, the gypsum beds at El Wak were considered as intercalated in the Jurassic limestone series.

The kunkar deposit of El Wak was again mentioned by W. D. Bell (1942) in an unpublished military report after a visit to the Northern Province during the Second World War.

F. Dixey (1948) after a reconnaissance of the area in 1943, in connexion with water-supplies, gave a general account of the geology of north-east Kenya. He named the Mandera Series and the Marehan Series. He considered that the Mandera Series underlay the Daua Limestone Series and described the lower part of the Marehan Series as representing a passage from the marine conditions during which the limestones were laid down to the terrestrial conditions when the Marehan sandstones were deposited. As a consequence the Marehan Series was dated as Jurassic.

During 1950-51 F. M. Ayers (1952) with the assistance of R. G. Murchison and A. O. Thompson mapped and described all the Jurassic sediments occurring in the north-eastern part of Kenya. Numerous sketches and maps accompany his report and include comprehensive columnar sections of the sediments. The Mandera Series was described and mapped as a facies variation of the Marehan Series, though in an appendix following Venzo (1948) it was suggested that part of the Mandera series was of Bathonian age. All information available at the time on the Mesozoic rocks of north-eastern Kenya was summarized by B. N. Temperley (1952) in a review of the Gondwana rocks of Kenya.

The confusion in the establishment of the sedimentary succession arose because none of the geologists except Ayers, who, however, covered a large tract of country in a relatively short time, was able to make more than a cursory investigation of the geology. Some of the confusion must be ascribed to Italian geologists working in Somalia. Since the Sacchi expedition (Angelis d'Ossat and Millosewich, 1900), various Italian geologists, notably Stefanini and Venzo, have described and correlated sediments of north-eastern Kenya with those of Somalia. Stefanini (1922, p. 1062), accepting the work of Sacchi, stated that the Lugh Group, a gypsiferous series of Triassic age, extended at least as far west along the Daua river as longitude 41°E., while Venzo (1948) dated what is now known to be the upper part of the Mandera Series as Callovian-Bathonian.

The following table illustrates the earlier geologists' contributions, and the sequence established as a result of the present survey.

TABLE I—A COMPARISON OF INTERPRETATIONS OF THE SEDIMENTARY SUCCESSION IN NORTH-EAST KENYA

Periods	Glenday, (Weir, 1929)	Busk, 1939	Dixey, 1948	Ayers, 1952	Present Report
Cretaceous	Marehan Sandstones			Marehan Sandstones and Man- dera Series	Marehan Series
Upper			Marehan Sandstones		Mandera Series
Jurassic	Daua	Limestone			Daua Lime- stone Series
Middle and Lower Jurassic	Limestone	Series	Limestone Series	Limestone Series	(Base and underlying beds not ex- posed)
Trias or Earlier	Sandstones at Beila (?)	Marehan Sandstones	Mandera Series	Didimtu Beds Mansa Guda Formation	

NOTE.—Dotted lines denote unconformity.

III—PHYSIOGRAPHY

Physiographically the area can be divided into four regions; (1) the southern plains, (2) the hills in the west centre and north centre, (3) the hills on the eastern boundary, and (4) the Daua valley and its vicinity with dissected Pleistocene terraces.

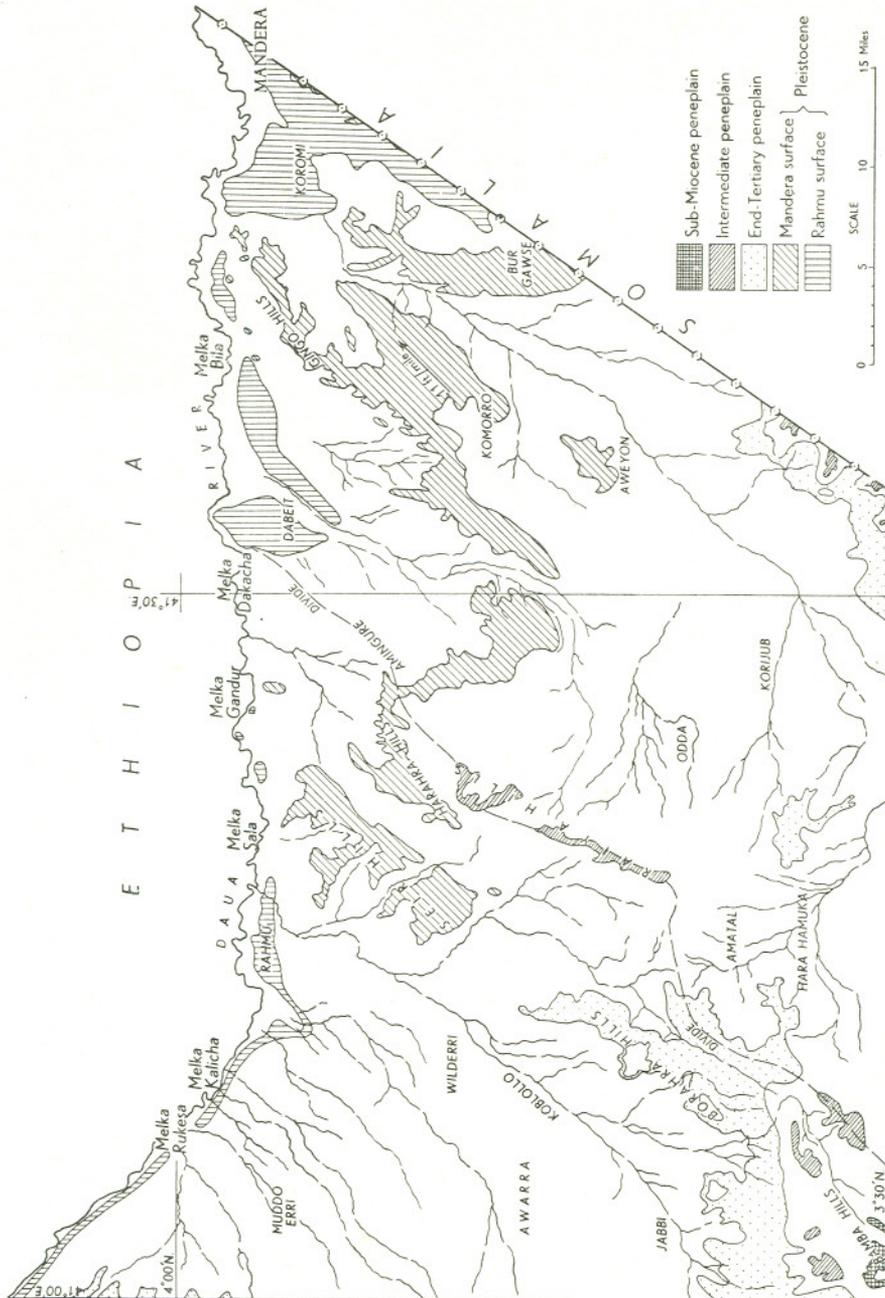


Fig. 1.—Physiographical map of the Mandera area.

The southern part of the area is a wide sandy plain, above which the flat-topped Danissa, Garri, Willeh, Bamba and Raiya hills rise in the west and the Hegalu hills on the eastern border of the area. The topography has reached an "old age" cycle in the south but, owing

to rejuvenating Pleistocene dissection, a "mature" stage is attained by the northern parts of the area. The hills are drained by numerous seasonal streams that disappear when they reach the plains or follow shallow courses, but when the stream-beds reach the shoulders of the Daua valley they have deeply incised courses. The topography is also influenced by alternating resistant limestone and non-resistant shaly horizons in the Jurassic succession, giving rise to low hill-ranges along the strike, enhanced by strike faulting such as has resulted in the prominent Hegalu hills.

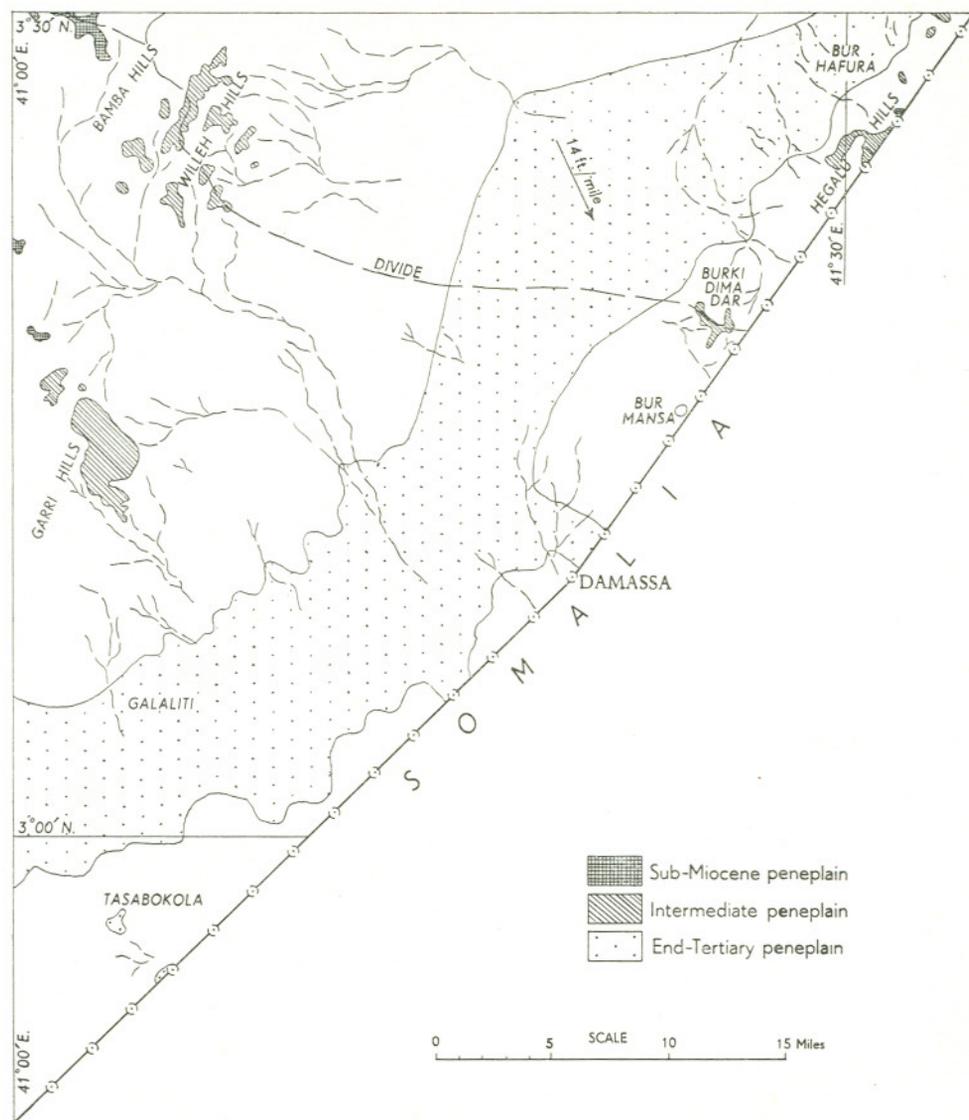


Fig. 2.—Physiological map of the Damassa area.

Two divides can be recognised in the area, one being the Bamba-Raiya-Amingure divide, which separates streams draining to the east and west respectively. The rivers flowing in both directions eventually drain into the Daua river, and the divide is gradually shifting eastwards with the resultant river capture north of the Bamba hills. The second divide, extending from the Bamba hills to Buski Dina Dar, separates streams flowing to the Daua from those draining towards depressions in the plain to the south.

The flat-topped Danissa, Garri and Bamba hills in the west are all bevelled in their highest parts at about the same elevation by a surface that also bevels the top of the Hegalu hills on the side east of the area (see Figs. 1 and 2). The extension of this bevel further west has been taken to represent the sub-Miocene peneplain by Saggerson and Miller (1957, p. 6). A less distinct but mappable erosion surface forms ledges along the flanks of the above-mentioned hills and is also preserved by the Marehan sandstone capping of the Raiya hills. It corresponds with the intermediate surface of Saggerson and Miller in the Takabba-Wergudud area. The intermediate surface occurs at levels approximately 300 feet lower than the sub-Miocene surface, and only attains considerable areal extent when preserved by resistant horizons in the Marehan Series. For the greater part the open sandy plain south-east of the hills represents the end-Tertiary peneplain (cf. Thompson and Dodson, 1958, p. 5; Saggerson and Miller, 1957, p. 6) which also bevels the Borahra hills, north-east of the Bamba hills, and reappears in the extreme north-west part of the area. Patches of laterite formed below the surface on the southern part of the end-Tertiary peneplain and have been exposed by Pleistocene dissection. The Tertiary peneplains have a gentle slope to the south-south-east which has been measured as approximately 14 feet per mile.

In the northern sector of the area in the vicinity of the Daua river, a sequence of Pleistocene terraces and deposits permit the unravelling of the Pleistocene history of the valley. The succession established is summarised in the following table:—

TABLE II—THE PLEISTOCENE TERRACES AND TERRACE DEPOSITS OF THE DAUA RIVER

PERIOD	Terrace Sequence	Deposits	Climatic Changes*	
PLEISTOCENE	Upper	3 m. terrace; flood level	Dusty grey soil	
		+ 3 m.	Alluvium	Gamblian Pluvial
	Middle	10 m. terrace—remnants	Yellowish brown calcareous soil	Kanjeran Pluvial
		+ 20 m.	Gypsite, grits, silty limestones and marls, conglomerates; dated by artifact	2nd Interpluvial
	Lower	30 m. terrace—Rahmu erosion surface	Sandy soil and calcrete	Kamasian Pluvial
		— 40 m.	Gypsum, sandstones, limestones, cherts, conglomerates	1st Interpluvial
	60 m. terrace—Mandera erosion surface	Extensive calcrete	Kageran pluvial	

*cf. Leakey, 1950, p. 63.

The Daua valley has a young appearance in the north-western part of the area where it has been cut deeply into the Jurassic sediments, but matures down-river to the east where it has been widened since the Tertiary. The Daua dates back at least to early Pleistocene times when, during the Kageran pluvial period the end-Tertiary peneplain was intensely dissected and the Mandera erosion surface was planed off. The Mandera surface slopes at 12 feet per mile towards the north-east, and forms a terrace 60 metres above the present river bed. It is obvious that this surface, which is widely covered by a calcareous crust, would not be so extensive now if its preservation had not been assisted by the presence of flat-dipping resistant limestone beds that outcrop at its elevation.

A second well-developed shelf, the Rahmu surface, extends along the valley 30 metres above the river bed. It is extensively covered by reddish-brown sandy soils in which a nodular calcareous layer has accumulated below the surface, the latter deposit being extensively exposed at and west of Rahmu. This terrace was probably formed during the second pluvial period during the dissection of the Mandera erosion surface. Remnants of a 10-metre terrace exist along the valley also (Plate 1b) and their formation can be ascribed to the third pluvial cycle. This terrace was largely destroyed during the subsequent pluvial period when the river bed was lowered approximately to its present level. A three metre alluvial terrace was then formed and now shelves the river-course along its entire length, being the approximate flood-plain level.

The profile of the Daua descends at four to five feet per mile, a slope which is largely adhered to by the Pleistocene terraces.

IV—SUMMARY OF GEOLOGY

The rocks of the area are all of sedimentary origin and range in age from middle Jurassic to Recent. They fall into three divisions—Cainozoic sediments, Cretaceous sediments and Jurassic sediments.

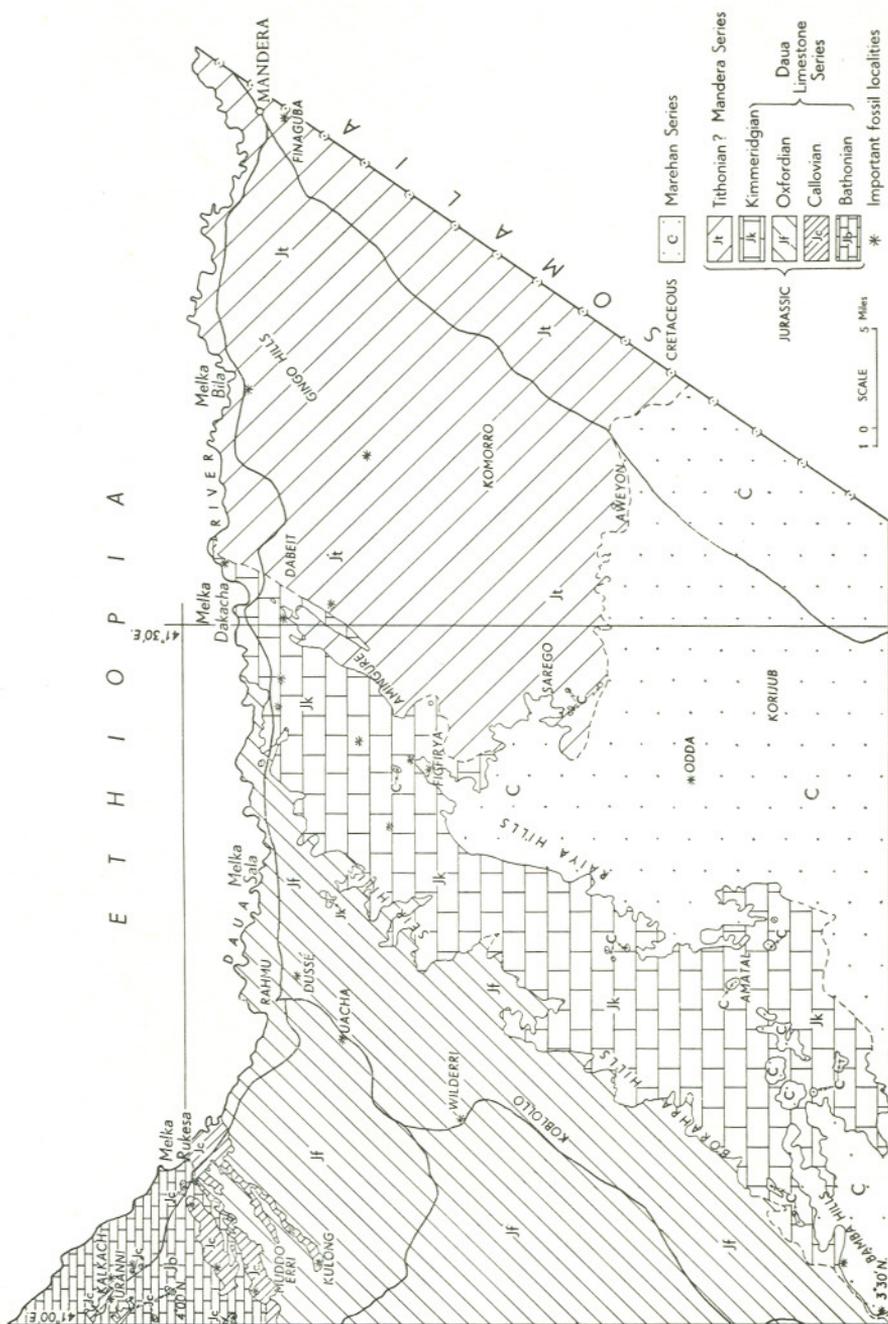


Fig. 3.—Map illustrating the distribution of the Mesozoic sediments in the Mandera area.

The Jurassic beds consist of two divisions; (1) the Daua Limestone Series consisting of limestones, argillaceous limestones and calcareous shales with minor shales and calcareous siltstones deposited during a transgressional phase of the Jurassic sea and (2) the Mandera Series consisting of a gypsiferous series of shales, mudstones, sandstones and limestones representing sediments laid down during the regression of the sea in uppermost Jurassic times. The Daua Limestone Series is divided into seven lithological units based on the varying amounts of argillaceous material in each, that represent continuous deposition from Bathonian to Kimmeridgian times and are dated by a prolific fauna in parts of the succession. Six thin but persistent dolomitic limestone horizons are present in the Mandera Series and aid the mapping and description of the succession. The regional dip of the Jurassic beds is 1° to 2° to the E.S.E., but variations occur in parts where minor N.N.W.-S.S.E. folding and major N.N.E.-S.S.W. folding and faulting have disturbed the sediments.

The Marehan Series, unconformably overlying the Jurassic System, is of Cretaceous age and consists of siltstones, sandstones, shales and limestones in the lower part, the Danissa Beds, and of massive sandstones with minor siltstones in the upper part, the Marehan Sandstones. The Danissa Beds were deposited mainly in an estuarine environment which was superseded by terrestrial conditions during which the Marehan Sandstones were deposited.

The distribution of the Mesozoic sediments in the northern part of the area is indicated in Fig. 3.

A variety of sediments including superficial deposits of soil and calcrete represent Cainozoic deposition, but consist mainly of lacustrine and fluvial deposits along the Daua river, accumulated largely during the inter-pluvial phases of the Pleistocene.

The stratigraphical succession is summarised in Table III which also indicates the major events that took place in Jurassic and later times.

TABLE III—STRATIGRAPHICAL SUCCESSION IN THE MANDERA—DAMASSA AREA

Eras	Periods	Representatives	Lithology and Thickness	Environment of Deposition	Climate	Palaeogeographic Events			
CAINOZOIC	Quaternary	Recent	Residual soils River deposits Awarra kunkar	Soil Alluvium Calcrete	Paludal ?	Dry and wet phases			
		Pleistocene	Upper	3 m. terrace soil El Wak Beds ? Terrace remnants in Daa valley	Dusty grey soil Gypsite and calcrete (70 ft.) Yellowish brown calcareous soil	Paludal ? Terrestrial	1st post-Pluvial dry phase Gamblian Pluvial 3rd Interpluvial	Erosion. Formation of 3 m. terrace.	
			Middle		Daa valley deposits Terrace deposits Shangalla Limestones and associated deposits	Gypsite, grits, silty limestones, marls and conglomerates. Sand, sandy soil and calcrete Limestones (50 ft.) conglomerates, gypsum and sandstone	Fluviatile (mainly) Terrestrial Lacustrine and fluviatile	Kanjeran Pluvial 2nd Interpluvial Kamasian Pluvial	Erosion. Formation of 10 m. terrace. Erosion. Formation of Rahmu erosion surface.
				Lower	Deposits on Mandera erosion surface Borahra Lacustrine deposits	Pebbles, calcrete and sandstone Calcareous silt, gypsum, chert (60 ft.)	Terrestrial Lacustrine	1st Interpluvial Kageran Pluvial	Erosion. Formation of Mandera erosion surface.

TABLE III—STRATIGRAPHICAL SUCCESSION IN THE MANDERA-DAMASSA AREA—(Contd.)

		Eras	Periods	Representatives	Lithology and Thickness	Environment of Deposition	Climate	Palaeogeographic Events		
MESOZOIC	CAINOZOIC	Tertiary	Pliocene	Laterite	Laterite and soil	Terrestrial	Semi-arid	Extensive erosion and Peneplanation.		
			Miocene							
			Oligocene							
			Eocene							
			Cretaceous	Lower	Marehan Series { Marehan Sandstones Danissa Beds	Sandstones, siltstones (350 ft.) Siltstones, sandstones, shales, limestones (380 ft.)	Terrestrial Marine and estuarine	Semi-arid ?	Marine regression. Rejuvenation of faulting.	
				Upper	Mandera Series	Shales, mudstones, sandstones, limestones (2,000 ft. ?)	Mainly lagoonal		Marine transgression Folding and faulting Marine regression	
			Jurassic	Middle		Daua Limestone Series { Dakacha Limestones Hereri Shales	Mainly argillaceous limestones (300 ft.) Mainly gypsiferous shales (200 ft. ?)	Marine	Warm	Marine transgression with several periods of slight regression.
						Muddo Erri Limestones Rukesa shales Murri Limestones	Limestones, calcareous shales (1,000 ft.) Mainly calcareous shales (400 ft.) Limestones and calcareous shales (320 ft.) Mainly calcareous shales (180 ft.) Limestones (525 ft. exposed)			

NOTE.—Dotted lines denote unconformities.

V—DETAILS OF GEOLOGY

1. Jurassic System

(1) DAUA LIMESTONE SERIES

The series of limestones and shales outcropping in the north-western part of the area was named the Dava Limestone by Weir (1929, p. 9), though the beds were later referred to by various writers (Dixey, 1948, p. 34; Ayers, 1952, p. 5) as the Limestone Series following on their original naming by Glenday (1923, pp. 29-30). In recent years the term Dava Limestone Series has been resuscitated (Saggerson and Miller, 1957, p. 10) and as it is considered to be a preferable name it will be used in this report.

The eastern boundary of the Dava Limestone Series in the present area occurs at a line connecting the Bamba hills with Melka Dakacha along which the Kimmeridgian limestones disappear under the overlying Marehan Series as far north as Figfiryra and after that under the Mandera Series. Except for soft shale horizons, exposures are good along the Dava river but become poor further south where the rocks are mostly covered by kunkar. At Rahmu and south and south-west of Rahmu, the Jurassic rocks are covered by lacustrine deposits, probably of Pleistocene age, as well as by Recent crustal and fluvial deposits. Relatively small outcrops of the upper beds of the Dava Limestone Series also occur along the western slopes of the Hegalu hills.

Because of the low regional dip, which varies between 1° and 2° to the E.S.E., as well as the presence of gentle folds of small amplitude usually striking N.W.-S.E., local dip readings are often misleading and, therefore, dip measurements taken from a distance along the flanks of the hills were used as a measure of regional dip and for calculating thicknesses in areas where exposures are poor. Aneroid barometer readings down the dip slopes of beds were also measured over distances of up to 12 miles in attempts to calculate regional dip but were found to be inaccurate, either because of the inaccuracy of the aneroid or because of the mild arching of the beds.

The Dava Limestone Series can be divided into seven lithological groups as shown in the following table, where they are correlated with Jurassic sediments in coastal Kenya and in Ethiopia.

TABLE IV—THE JURASSIC SUCCESSION IN THE MANDERA-DAMASSA AREA AND ITS CORRELATION

	Stages	Coastal Kenya (Caswell, 1956, p. 19)	Mandera Area	Ethiopia (Taylor, 1948 B)
Upper Jurassic	Tithonian	Not exposed	Mandera Series	Main Gypsum
			Dakacha Limestones	Gabredarre Formation
	Kimmeridgian	Changamwe Shales with lenticular lime- stone bands	Hereri Shales	Uarandab Formation
			Seir Limestones	Hamanlei Formation
	Oxfordian	Rabai Shales	Rahmu Shales	?
			Muddo Erri Limestones	
Middle Jurassic	Callovian	Miritini Shales	Rukesa Shales	
	Bathonian	Kibiongoni Beds	Murri Limestones	
		Kambe Limestones		

In dating the various parts of the Jurassic succession in the present report, the stage divisions as laid down in a report by Ayers (1952, pp. 27-31) in which both stratigraphical and palaeontological data are taken into consideration, are adhered to. Earlier palaeontologists had no clear stratigraphical guidance when dealing with the collections of fossils made in this part of Kenya. The appendix to this report is a complete list of the fossils collected during the survey as identified to date, as well as those described by Ayers (1952) and Weir *et al* (1929), and shows their age range.

(a) *Murri Limestones*

A series of thick-bedded, oolitic and algal limestones in the Melka Murri area, north-west of the present area, forms part of the Lower Limestones of Ayers (1952, p. 9) and has since been referred to as the Murri Limestone Series by Thompson and Dodson (1958, p. 15). The series consists of more than 1,700 feet of nearly uniform limestone, but only the upper part, some 500 feet in thickness, is exposed in the extreme north-western part of the Mander area.

At Melka Biini the Daua river has cut a deep channel and exposed approximately 515 feet of well-bedded grey, cream and brown massive limestones of the Murri Limestone Series. They are the oldest rocks exposed in the area and are presumed to underlie the whole of it.

The sequence is as follows:—

	<i>Thickness</i> (feet)
4. Yellowish brown shelly limestone	25
3. Yellowish brown limestone	55
2. Grey argillaceous limestones with intercalations of buff limestones and thin cream porcellaneous limestones..	325
1. Buff fine-grained limestone with thin argillaceous limestone intercalations	110

The lowest limestones in the succession are thick-bedded and form a cliff along the river. The next group above is poorly exposed in parts but appears to consist mainly of grey argillaceous limestones intercalated with buff recrystallized limestones, some of which are oolitic, and thin cream porcellaneous limestones. Shale partings are common within the argillaceous limestone while thin calcareous shale beds become more frequent higher in the succession, where they often contain a few fossils. The overlying yellowish brown limestone forms the major part of the dip-slope between Kalkach Uranni and Melka Rukesa. It is well-exposed in the Rukesa river where it is mildly folded along N.W.-S.E. axes, and contains rare, poorly preserved fossils in a feebly oolitic matrix. The uppermost 25 feet of yellowish brown shelly recrystallized limestones are usually poorly exposed but outliers and red-weathered boulders occur on the slopes of the Rukesa valley. The limestones are composed mainly of shell fragments, ooliths and numerous echinoid spines (?). Occasional nodules of argillaceous material render the horizon even more distinctive. Under the microscope the rock is seen to consist of ooliths with both radial and concentric structures, and of fossil fragments cemented by finely crystalline calcite. A few small quartz and felspar grains as well as a few foraminifera are sparsely scattered throughout the thin section prepared (specimen 8/6*), the clastic grains usually forming the kernels of ooliths.

At the top of the shelly limestone the lithology changes abruptly, the overlying rocks being more argillaceous. The fossil assemblages obtained from the overlying rocks indicate that the Murri Limestones form part of the Bathonian stage. The fossils yielded by the rocks of Bathonian age at localities west of the present area were listed by Ayers (1952, p. 27) and Weir *et al.* (1929, pp. 11 and 14).

During the present survey the following fossils were collected two miles west of Melka Biini and, according to Dr. Cox, are in keeping with a Bathonian age:—

- Brachidontes (Arcomytilus) asper* (J. Sowerby),
- Chlamys curviviarians* (Dietrich),
- Lima (Plagiostoma) sp. nov.?*,
- Ostrea (Liostrea) sp. indet.*

Undoubtedly the Murri Limestones or their equivalents occupy a large tract of country in south-eastern Ethiopia. The lower part of the Bardera Group of south-western Somalia is of similar age, and is a shelly limestone containing *Megalodon*, *Isogonomon*, and *Gervillia* (Stefanini, 1925, p. 1063). Deposits of Bathonian age also exist along the Kenya coast where they are represented by most of the Kambe limestones and the shales and sandstones of the Kibiongoni Beds which are now regarded as a lateral facies variation of the Kambe limestones (Caswell, 1953, p. 22; 1956, p. 19). The Ngerengere Beds, the Kidugallo Limestone, and part of the silty shales and marls of the overlying Station Beds in Tanganyika,

*Numbers prefixed by 8/ , 16/ , and 24/ , refer to specimens in the regional collections of the Geological Survey of Kenya.

south-west of Dar es Salaam, are probably contemporaneous (King, 1954, p. 16). Some fossils derived from the Jurassic beds of Tanganyika were listed by Wade (1937, p. 48). A good fauna of Bathonian age occurs in marine deposits along the western margin of Madagascar, where the rocks are mainly limestones and marls, the limestones often being oolitic (Besairie, 1946, pp. 15-17). Further south their place is taken by sandstones of Isalo type with intercalated gypsiferous and lignitic shales (Hirtz, 1949, p. 30).

(b) *The Rukesa Shales*

The Murri Limestones are succeeded by a relatively thin fossiliferous series of light green shales and argillaceous limestones with occasional hard brownish recrystallized limestone intercalations. The recrystallized limestones, which often contain colonial corals, weather to a distinctive dark yellow colour, while the shales and argillaceous limestones have a dead white colour. The group is well exposed along the flanks of the low hills south of Melka Rukesa, and forms outliers on the dip-slope of the limestone country to the west, where it has been preserved by the resistant recrystallized limestone horizons. Here numerous fossils are found lying scattered on the surface, having been weathered out from the upper beds of the low hills forming the outliers.

The sediments at Melka Rukesa were described by Glenday as a series of shales and muddy limestones with some sandy limestones (Weir, 1929, pp. 11 and 15). Ayers (1952, pp. 9-10) mentioned the local development of shales within his Lower Limestone group of the Daa Limestone Series, while Thompson and Dodson (1958, p. 19) referred to equivalent deposits in the Derkali-Melka Murri area to the west as the Asaharbito Beds.

The succession of the Rukesa Shales as recorded at Kalkach Uranni and Melka Rukesa is as follows:—

	<i>Thickness</i> (feet)
10. Brown recrystallized limestone	5
9. Light grey calcareous shales with thin grey argillaceous limestones	40
8. Grey massive argillaceous limestone	3
7. Grey argillaceous limestone with thin calcareous shale beds and partings	12
6. Brown shelly recrystallized limestone	$\frac{1}{2}$ -1
5. Light grey calcareous shales with argillaceous limestone intercalations in the upper part, and with shales, greenish-grey and less calcareous, in the lower part	80
4. Brown recrystallized limestone	2
3. Grey argillaceous limestones and shales	30
2. Fossiliferous recrystallized limestone	1
1. Grey argillaceous limestone (poorly exposed)	c.10
TOTAL THICKNESS	184

Beds 3, 5 and 9 weather easily and yield numerous well-preserved lamellibranchs and brachiopods with occasional echinoids. The brown recrystallized limestones contain numerous fossils, but only occasionally yield determinable specimens. Of these beds, horizon 6 is distinguished by being sandy and by often containing colonial corals at Melka Rukesa. Beds 6, 7 and 8 can be used as a marker group as they are bounded above and below by soft argillaceous horizons and appear as a conspicuous 15-ft. cliff along the slopes of the hills.

A thin section of a coral-bearing rock (specimen 16/178) derived from bed 6 shows that it consists of a finely crystalline calcite mosaic enclosing a few rounded patches consisting of radiating fibres of quartz, which also rarely occurs interstitially. Angular grains of quartz are also sporadically present singly or in clusters in patches of coarsely recrystallized calcite, and are evidently authigenic.

A thin section of a clay (specimen 8/7), from bed 5, collected in the Kalkach Uranni area, shows that it is a highly calcareous rock. Sub-angular to angular clastic grains of quartz and felspar occur scattered throughout the rock and shells and shell fragments, including foraminifera, are abundant.

In Ayers (1952, pp. 24 and 28) and Weir (1929, p. 15) the following fossils are listed as derived from the Rukesa Shales:—

Burmihynchia subversabilis Weir,
 ?*Cymatorhynchia quadriplicata* Muir-Wood,
Somalirhynchia sp.,
S. africana Weir,
S. somalica (Dacqué),
S. tumida Muir-Wood,
S. stefanii Weir,
Cererithyris cf. *dorsetensis* Douglas and Arkell,
Ptyctothyris quillyensis (Bayle),
Pseudoglossothyris sulcata Muir-Wood,
Camptonectes lens (J. de C. Sow.),
Chlamys baden-powellii Weir,
C. aff. palmyrensis (Krum.),
Entolium solidum (Roem.),
Velata abjecta Müll.,
V. inaequistrata (Futt.),
Lima (*Plagiostoma*) *harronis* Dacq.,
L. (Plagiostoma) subcardiiformis Greppin,
Exogyra nana (J. Sow.),
 ?*Gryphaea* sp.,
Lopha sp.,
L. solitaria (J. de C. Sow.),
L. costata (J. de C. Sow.),
Eligmus rollandi Douv.,
E. rollandi var. *laevis* Douv.,
Arctostrea rastellaris Münst.,
Astarte minima Angelis d'Ossat,
Astarte sp.,
Coelastarte sp. (?*C. excavata* var. *asiatica* Douville),
Opis (*Trigonopsis*) cf. *viridunensis* Buv.,
Mactromya rugosa Weir,
M. cf. aequalis Ag.,
M. aff. impressa Mor. and Lyc.,
Protocardia sp.,
Lucina cf. *lirata* Phil.,
Corbis aff. *lajoyei* d'Arch.,
Fimbria sp.,
Ceratomya wimmisensis (Gill.),
Ceromyopsis sp.,
Pholadomya carinata Goldf.,
P. protei (Brongn.),
Homomya gibbosa (J. Sow.) or *H. crassiuscula* Lyc.,
Quenstedtia sp.,
Globularia sp.

In a discussion of the age of the beds, Weir (1929, p. 15) gave it as his opinion that although the genus *Cererithyris*, which would indicate a Bathonian age, is apparently represented in the fauna (he was not certain that it was derived from Melka Rukesa) the assemblage as a whole could be regarded as Corallian-Kimmeridgian in age. The brachiopods obtained from the Rukesa Shales by Ayers (Ayers, 1952, p. 24, locality 8/5) were dated as Argovian by Dr. Muir-Wood, though the lamellibranchs were ill-preserved and their ages indeterminate. The shales were, however, dated as Callovian in the second appendix to the Ayers' report (1952, p. 28), where it is stated that some of the forms have a Bathonian aspect and the fauna may be transitional or the lithological change that guided collection may lie a little below the presumed Callovian base. It was also suggested that the specimens identified by Weir were collected at a locality further east, where higher horizons could be expected.

During the present survey a fossil, identified as a new species of the nautiloid *Paracnoceras*, were collected at Rukesa. Dr. Spath considers it as probably of the group of *P. dorso-excavatus* (Parona and Borarelli), which is of Callovian age. The following additional brachiopods were also found in the Rukesa shales at Rukesa:—

Somalirhynchia stefaninii Weir var.,
S. hadramautensis (Stefanini),
Somalithyris sp.,
Avonothyris (?) sp.,
 "Terebratula" cf. *ferrandii* Stefanini.

These brachiopods were identified by Dr. Muir-Wood, who dated them as Callovian-Oxfordian or younger. A Callovian age, however, is borne out by the following lamelli-branches and gastropods collected recently from these beds and identified by Dr. Cox:—

Arca (*Eonavicula* ?) sp.,
Chlamys curvivarans (Dietrich),
Eopecten abjectus (Phillips),
E. aubryi (Douvillé),
Ostrea (*Liostrea*) sp.,
O. (*Catinula*) cf. *ancliffensis* Cox and Arkell,
Lopha gregarea (J. Sowerby),
Anisocardia minima (J. Sowerby),
Corbis lajoyei d'Archaic,
Mactromya aequalis Agassiz,
Ceratomya concentrica (J. de C. Sowerby),
Ceromyopsis kiliani Rollier,
Pholadomya inornata J. de C. Sowerby,
P. lyrata J. de C. Sowerby,
Cercomya ? sp. nov.,
Pleuromaria ? sp.,
 "Aporrhais" sp. indet.,
Nerinea sp. indet.,
Cylindrites sp. indet.

Sediments of Callovian age extend from north-eastern Kenya through Ethiopia into Somaliland Protectorate and are also exposed in Somalia. In Somaliland the Bihen Limestones, dated as possibly Callovian-Divesian (Macfadyen, 1933, p. 28) occur at the base of the Jurassic succession and are massive and locally argillaceous, dense limestones. In the Bardera area of Somalia according to Stefanini (1925, p. 1,063–1,064), the Callovian is represented by yellow and rose-weathering marly limestones overlain by a compact shelly bed with a fauna indicating a transition between the Callovian and Oxfordian stages.

The Miritini Shales of Coastal Kenya, a series of dark grey to black shales dated by ammonites (Caswell, 1953, p. 23), were also deposited during Callovian times. In Madagascar the Callovian stage is represented by gypsiferous marls (Besairie, 1946, pp. 17–18).

(c) *The Muddo Erri Limestones*

The Rukesa shales are overlain by the Muddo Erri Limestones, which consist mainly of grey argillaceous limestones interbedded with minor calcareous shales in their lower part and buff oolitic and shelly limestones in their upper part. Calcareous siltstones are encountered higher in the succession and the group terminates with a distinctive calcareous siltstone horizon approximately 15 feet thick. Exposures of the lower parts of the succession are adequate, but outcrops representing the upper Muddo Erri Limestones are more rare and they are often hidden by Quaternary deposits. When this is the case the incomplete sequence could only be determined from occasional outcrops in small gullies and from sporadic float blocks.

The locality of Muddo Erri is well known to the indigenous population because water in small quantities can be obtained there throughout the dry season by digging in the dry river bed. Sacchi (Angelis d'Ossat and Millosewich, 1900) visited the locality (which he called Muddo Erelle) on his expedition to the west and computed that it is situated approximately on longitude 41°E. Stefanini, (1925, p. 1,062) supposed that the Triassic Lugh Group extended along the Daua river from the east at least as far as Muddo Erri, but the subsequent discovery of numerous Jurassic fossil beds east of the locality exposed the error of earlier observers. Muddo Erri became known as a fossil locality through the collection of Glenday (Weir, 1929, pp. 11 and 14). Ayers (1952, pp. 9 and 10) regarded the Muddo Erri Limestones as part of his Lower Limestone group.

The lower part of the Muddo Erri Limestones succession was measured at different localities where exposures are good, correlations being based on the lithological sequence determinable at Muddo Erri.

Melka Kalicha	Thickness (feet)	Muddo Erri	Thickness (feet)	Kulong	Thickness (feet)
				Brownish - yellow fossiliferous recrystallized limestone	5
				Light grey calcareous fossiliferous shales with thin intercalated yellowish - brown recrystallized limestones	40
		Brown recrystallized limestones with argillaceous limestone bands	15	Brown massive crystallized limestones	15
		Dark grey massive argillaceous limestones	15	Dark grey massive limestone exposed in river bed	?
		Brown oolitic shelly limestone	8		
		Yellowish - brown recrystallized fossiliferous limestone	1		
3. Brown fine-grained oolitic limestone	15	Oolitic limestone with local development of shale and intra-formational conglomerate	c. 30		
2. Argillaceous limestones and thin calcareous shales; well-bedded	80				
1. Massive grey, argillaceous limestone with a thin porcellaneous limestone band near base	c. 20				

From these measurements it can be seen that the lower part of the succession is approximately 215 feet thick. From small scattered outcrops and float in the vicinity of Kabii and Kordayu, about six miles south and south-west of Muddo Erri, as well as along Lugh Kalmalub near Melka Kalicha in the Daua valley, it is concluded that the upper part of the Muddo Erri Limestones consists of a sequence of buff and cream oolitic and shelly limestones, with a thin band of calcareous siltstones at the top. The thickness of the limestones is calculated to be at least 90 feet and the calcareous siltstones are 15 feet thick, so that the total thickness of the Muddo Erri group is at least 320 feet. The two parts of the limestones are not separated on the map, but the calcareous siltstone is a distinctive marker bed and has been given a different colour from the rest of the group.

Under the microscope the argillaceous limestones appear as fine-grained calcite mosaics, usually dense with included argillaceous material, and containing patches of slightly coarser, clear crystals of calcite. The recrystallized limestones are composed of mosaics of clear calcite crystals, often with ferruginous interstitial patches. Fossil shells appear in the thin sections as slightly curved lenticles of clear calcite which are often fibrous-looking, with fine-grained slightly ferruginous borders defining the outline.

The porcellanous limestone band near the base of the succession is a distinctive type and is the only limestone of this kind encountered above the Bathonian beds, in which such limestones are not infrequent. They are usually yellowish buff in colour, fine-grained, homogeneous and with distinctive conchoidal fracture. The microscope reveals that the band in the Muddo Erri beds (specimen 16/174) is a very fine-grained calcitic mosaic containing patches and irregular veinlets of clear calcite and numerous small fragments of shells and other organic debris. Small, usually rounded, aggregates of limonite are scattered throughout the thin section.

The oolitic limestones of the upper parts of the Muddo Erri Limestones are mostly light brown, buff or cream in colour, the ooliths being variable in size and prominent because of slight difference in tint from their recrystallized calcite matrix. The ooliths, which have both radial and concentric structure, often enclose a core of clear crystalline calcite, but sometimes have formed round fine-grained calcareous kernels and rarely round foraminifera. Ooliths containing more than one kernel are only rarely encountered. The ooliths are usually evenly distributed, but are sometimes concentrated in layers imparting an indistinct banded appearance to the rocks. One specimen (16/184, from 5½ miles south-west of Muddo Erri) also contains rounded fragments of fine-grained calcareous rocks that were probably derived by the erosion of previously deposited sediments. Oolitic fragments with dense matrices, in addition, indicate contemporaneous erosion. Shell fragments are usually present in small amounts, but sometimes their number increases to such an extent that the rocks grade into shelly limestones. Specimen 16/183 from five miles south-west of Muddo Erri contains, in addition to shell fragments, whole echinoids, oysters and belemnites cemented by a recrystallized calcite matrix with numerous ooliths.

The shelly limestones usually consist of a mosaic of calcite crystals enclosing numerous shell fragments, but specimen 16/142, from two miles south of Muddo Erri, has a fine-grained carbonate matrix with coarsely recrystallized calcite and some chert-like silica partly replacing the interiors of shell fragments. The ooliths in this rock are patchily limonitized, and there are several fragments of oolitic rock. Quartz is encountered in some of the specimens as small irregular replacive pools or as rare small clastic grains, usually in association with a few small clastic feldspar grains. Small patches of limonite are not uncommon and are often segregated around the peripheries of clear recrystallized calcite patches. Foraminifera are nearly always present and are sometimes an important constituent. Corals are present at the exposures five miles south-west of Muddo Erri.

A calcareous siltstone collected four miles south of Muddo Erri (16/144) is a red fissile rock, breaking easily along the bedding planes, that reacts strongly with dilute hydrochloric acid. The microscope reveals a mosaic of clastic quartz and feldspar (orthoclase and plagioclase), with average grain size of about 0.1 mm., cemented by carbonate stained by limonite. Tourmaline and zircon grains are common, while detrital carbonate occurs as small grains containing a high percentage of limonite. Monazite occurs as rare grains and there is a little muscovite in addition to sericite in the feldspars. Sparse shell fragments are present as well as occasional foraminifera.

The red-brown siltstones occurring at the top of the Muddo Erri Limestones show no banding on fresh fractures, but well-developed current bedding is displayed on weathered surfaces. Under the microscope they are seen to consist of 60 per cent clastic material with average grain size about 0.1 mm. cemented by a rather dirty fine-grained calcite matrix (specimen 16/173). The clastic grains comprise quartz, orthoclase and oligoclase with minor chalcedony, zircon and tourmaline, while sphene, muscovite, chlorite and fluorite (?) occur as accessories. A few small fossil shell fragments are also recognizable. A characteristic of these rocks is the occurrence of lenticular calcite arranged parallel to the bedding. It is clear from the composition of the detrital content of the siltstones that the clastic grains were derived from the Basement System rocks to the west of the area mapped.

The following fossils have been listed as occurring in the Muddo Erri Limestones (Weir, 1929, pp. 11, 14-15); (Ayers, 1952, p. 23, locality 16/41 and p. 28):—

- Clypeus* (?) sp.,
- Clypeus* cf. *rostellus* Currie,
- Burmihynchia subversabilis* Weir,
- Kallirhynchia* sp.,
- Kallirhynchia* cf. *obsoleta* (Sow.),
- Cymatorhynchia* (?) *quadriplicata* Muir-Wood,
- Somalirhynchia africana* Weir,
- S. tumida* (?) Muir-Wood,
- S. stefaninii* Weir,

Lobidothyris cf. *aulites* (Stefanini),
Charltonothyris africana var. Weir,
Stiphrothyris sp.,
Avonothyris jordanensis Muir-Wood, juv.,
Chlamys aff. *palmyrensis* (Krum.),
Velata sp.,
Lima (*Plagiostoma*) cf. *rigida* Sow.,
L. (Plagiostoma) subcardiiformis Weir, (non Greppin),
L. (Plagiostoma) sp.,
Arctostrea costata (J. de C. Sow.),
Liostrea sp.,
 Giant oysters,
Heligmus polytypus Eudes-Deslongchamps,
H. asiaticus Douv.,
Mactromya rugosa Weir.,
M. cf. aequalis Ag.,
Ceratomya wimmisensis (Gill.),
Ceromyopsis cf. *aequatorialis* (Müll.),
Homomya sp. or *Phacaclomya* sp.

In addition, the following brachiopods collected during the present survey have been identified by Dr. Muir-Wood, who dates the fauna as Callovian to Oxfordian-Corallian.

Septirhynchia sp.,
S. cf. azaisi (Cottreau),
S. pulchra Muir-Wood and Cooper vars.,
S. pulchra Muir-Wood and Cooper,
Somilirhynchia subversabilis (Weir),
S. somalica (Dacqué),
S. africana mesoloba Muir-Wood,
S. hadramautensis (Stefanini),
S. stefaninii Weir vars.,
Pseudoglossothyris (?) *sulcata* Muir-Wood,
 "Terebratula" cf. *jubaensis* Weir.

The dating indicated by the brachiopods is in agreement with that found by Dr. Cox for lamellibranchs from Muddo Erri and Kulong, though some of the fossils collected were derived from the upper Rukesa Shales which are also exposed there:—

Eonavicula cf. *minuta* (J. de C. Sowerby),
Brachidontes (Arcomytilus) asper (J. Sowerby),
B. (Arcomytilus) ? sp.,
Trigonia sp. indet.,
Entolium demissum (Phillips),
Camptonectes lens (J. de C. Sowerby),
Chlamys curvivarans (Dietrich),
Eopecten aubryi (Douvillé),
Lima (Plagiostoma) cf. *schardti* de Loriol,
L. (Plagiostoma) strigillata Laube,
L. (Plagiostoma) cf. *complanata* Laube,
L. (Plagiostoma) cf. *jumaraensis* Cox,
L. (Plagiostoma) n. sp.,
Pseudolimea duplicata (J. de C. Sowerby),
Ostrea sp., indet.,
O. (Liostrea) sp.,
Eligmus rollandi Douvillé,
Corbis lajoyei d'Archiac,
Lucina sp.,
Protocardia ? sp. indet.,
Mactromya aequalis Agassiz,
Ceratomya cf. *concentrica* (J. de C. Sowerby),
Ceromyopsis kiliani Rollier,
Pholadomya ovalis (J. Sowerby),
Pholadomya sp.,
Straparollus sp. indet.,
Aporrhais sp.,
Globularia sp. indet.

Weir (1929, pp. 14-15) on palaeontological grounds correlated the topmost beds of the succession exposed at Muddo Erri with the base of the succession at Melka Rukesa, which he had dated as Corallian. The stratigraphical succession as mapped refutes this assertion as well as his dating of the lower part of the sequence at Muddo Erri as Bajocian-Bathonian on the presence of the *Heligmus asiaticus* fauna. Weir also identified *Exogyra nana* and *Chlamys* sp. from Galitcha (Melka Kalicha) and suggested correlation of the beds from which they were derived with beds at Dabeir some 60 miles further south-west. He considered that the Dabeir beds are not older than Corallian and probably Kimmeridgian.

Dr. Muir-Wood considered that the *Somalirhynchia tumida* (?) of the Ayers collection probably indicated an Argovian age, though Dr. Cox considered that the age of these sediments was Bathonian or Callovian in view of the presence of *Heligmus* and *Ceratomya wimmisensis*. Taking the evidence as a whole it seems likely that the Muddo Erri beds include the lowest part of the Oxfordian stage in the Mandera area, though they probably also extend down into the Upper Callovian.

(d) *The Rahmu Shales*

West and south-west of Rahmu small isolated outcrops of dark grey shales with thin calcareous shales and argillaceous limestones indicate that the sediments overlying the Muddo Erri Limestones are mainly argillaceous. Although extensive Quaternary deposits conceal most of their width, a 75-foot high exposure occurs at Uacho in the valley west of the road, four miles south-west of Rahmu. Further to the south where Recent soils and kunkar occupy large areas, the shales are not exposed.

Ayers (1952, p. 10) described these shales as forming the major part of his Middle Shales group of the Daua Limestone Series and ascribed to them a thickness of approximately 100 feet on his composite columnar section, though in the text he realised that the beds must be several hundreds of feet thick and suggested a possible thickness of 300 feet. Exposures occur at the margins of a belt over five miles wide in the direction of dip and a calculation shows that the Rahmu Shales must be nearly 400 feet thick, assuming that there is no serious disturbance by folding or faulting.

The lowest exposed beds of the Rahmu Shales occur in a small gully west of Yabuchu. Here 20 feet of soft greenish shales with regular thin bands of argillaceous limestone crop out, fossils being represented by a few poorly preserved terebratulids and gastropods. Higher in the succession, on the slope of the hillock to the north, a 2-ft. sandy oolitic limestone is the lowest bed exposed, and is overlain by 35 feet of grey shales and calcareous shales and a 2-ft. fine-grained limestone, the succession being capped by Pleistocene deposits.

The main exposure at Uacho consists of 80 feet of monotonous dark grey friable shales and calcareous shales, with minor argillaceous limestones that weather into cobbles of various sizes, depending on the thickness of the bands. Other small exposures have been located and their identity as Rahmu Shales can always be affirmed by the numerous rhynchonellids scattered on the surface around them.

The calcareous nature of the Rahmu Shales is revealed by their strong reaction with hydrochloric acid and the high interference tints under crossed nicols of most of the very small grains forming the matrix. The microscope also disclosed the presence of scattered, very small clastic grains, which are as abundant in these shales as in any other of the shales of the Daua Limestone Series microscopically examined.

Fossils collected from the Rahmu Shales were listed in Ayers (1952, pp. 24, 25, 26 and 29) as follows:—

- Astrocoenia somalica* Thomas,
- Montastrea* sp. aff. *lifoliana* (Michelin),
- Crinoid stems,
- Somalirhynchia* sp.,
- S. africana* Weir,
- S. africana* var. *mesoloba* Muir-Wood,
- S. bihendulensis* Weir, amend Muir-Wood.
- S. smelliei* Weir,
- S. tumida* Muir-Wood,
- cf. *Terebratula* cf. *longisinuata* Krumbeck,
- T. cf. suprajurensis* Thurmann,

"*Terebratula*" *beirutiana* Krumbeck,
Mytilus jurensis Roemer,
Brachydontes (Arcomytilus) laitmairensis de Lor.,
Pinna (Stegoconcha) sp.,
Camptonectes lens (J. de C. Sow.),
Entolium demissum (Phill.),
Lima (Plagiostoma) sp.,
Exogyra sp. nov.,
Lopha gregarea (J. Sow.),
L. marshi (J. Sow.),
L. solitaria (J. de C. Sow.),
 ? *Fimbria* sp.,
Nautilus sp.,
Biplices aff. *africanus* (Dacq.),
Peltoceratoides cf. *constantii* (d'Orb.),
Aspidoceras sp.,
Belemnopsis tangananensis (Futt.),
 Belemnopsids.

In addition to the above, *Somalithyris* sp. and *S. bihendulensis* Muir-Wood were collected during the present survey. Dr. Muir-Wood, who identified these fossils, suggests that they are of Oxfordian-Corallian age. Lamellibranchs collected from the Rahmu Shales during the survey and identified by Dr. Cox are:—

Grammatodon (Indogrammatodon) sp.,
Protocardia sp.,
Homomya sp. nov.

Various interpretations of age have been placed on the fossils collected earlier. Dr. Muir-Wood (in Ayers, 1952, p. 25) pointed out that the assemblage of brachiopods indicated an Argovian age, and Dr. Dighton Thomas commented that *Astrocoenia somalica* is known only in the Callovian-Argovian of Somaliland (*op. cit.*, p. 24). Dr. Cox dated the oysters as Bathonian to Kimmeridgian, most probably Corallian or Kimmeridgian, and also noted that *Mytilus jurensis* suggests a Kimmeridgian age (*op. cit.*, p. 25). Dr. Spath considered that the *Biplices* aff. *africanus* was probably uppermost Oxfordian or Kimmeridgian, but the later discovery of an *Aspidoceras* enabled Dr. Arkell to confirm that the Rahmu Shales are probably lower Oxfordian (*op. cit.*, p. 29), which is in agreement with the mapped stratigraphy.

(e) *The Seir Limestones*

The beds succeeding the Rahmu Shales are named after the hills east of Rahmu where the majority of the beds of the group are exposed. The lower part of the succession is argillaceous and therefore poorly exposed but includes, at Wilderri, perhaps the most prolific fossil-bearing horizon of the Jurassic sediments of north-eastern Kenya. These argillaceous horizons, Ayers (1952, p. 10) included in his Middle Shale group. At the base and on the lower slopes of the Seir hills several calcareous sandstones outcrop as resistant bands and can be traced on aerial photographs. The succeeding argillaceous limestones, limestones and shales form the Seir hills and constitute Ayers' Middle Limestones. Further south-west the continuation of the same beds constitutes most of the Furfurso hills and the lower slopes of the Borahra hills, and they are evident in the extreme south-west of the Manderu area as low kunkar-covered hills. In the hills south of Awarra the sandstones become more important and form dip-slopes. The sandstones and some associated beds are probably the equivalent of the Golberobe Beds of the Takabba-Wergudud area to the south-west (Saggerson and Miller, 1957, p. 13).

The succession at the fossiliferous locality at Wilderri is:—

	Thickness (feet)
6. Thin brown fossiliferous limestone	—
5. Grey argillaceous limestones	9
4. Brown recrystallized limestone	2
3. Grey argillaceous limestones with minor calcareous shales	40
2. Thin brown silty limestone	—
1. Calcareous shales, slightly gypsiferous and with thin brown limestone bands	30
	81

The stratigraphy and palaeontology of the beds exposed at Dussé are the same, though the succession is less complete. The rocks immediately overlying these lowest beds are not exposed, but south of Dussé the following succession is seen in a low hill:—

	<i>Thickness (feet)</i>
4. Brown fossiliferous limestone	5
3. Cobbly grey argillaceous limestones	30
2. Brown fossiliferous limestone	3
1. Cobbly light grey limestones	15
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Further to the east of Rahmu exposures are good and complete sequences can be measured. During the mapping two facts came to light, firstly that the sediments increase in thickness towards the east, i.e. towards the central part of the depositional basin, and secondly that sandy horizons increase in thickness along the strike towards the south while the limestone beds often become sandy in that direction.

The sequence of the upper part of the Seir Limestones is as follows:—

	<i>Thickness (feet)</i>
41. Recrystallized limestone, weathering brown, with <i>Velata</i> and <i>Nerinea</i> (?)	2
40. Cobbly argillaceous limestones with numerous terebratulids	20
39. Recrystallized limestones, becoming cross-bedded, sandy and fossiliferous to the south	10
38. Calcareous shales	20
37. Hard recrystallized limestone	1
36. Calcareous shales	15
35. Hard crystalline limestone	2
34. Calcareous shales and argillaceous limestones	20
33. Prominent compact argillaceous limestones	20
*32. Argillaceous limestones and calcareous shales	20
*31. Recrystallized limestone	1
*30. Argillaceous limestones and calcareous shales	20
*29. Massive hard recrystallized limestone	4
28. Argillaceous limestones with <i>Meleagrinnella</i> and corals	40
27. Massive argillaceous limestone	3
26. Calcareous shales and thin argillaceous limestones— 20 feet thick five miles to the east	15
25. Prominent hard finely recrystallized limestone	4
24. Calcareous shales and thin argillaceous limestones with distinct oolitic band	50
23. Blocky argillaceous limestone with large gastropods	1
22. Calcareous shales with thin argillaceous limestones	14
21. Compact blocky argillaceous limestone	1
20. Calcareous shales with thin argillaceous limestones	20
19. Sandy recrystallized limestone	1
18. Calcareous shales with thin argillaceous limestones and a band of recrystallized limestone	30
17. Recrystallized limestone	3
16. Flaggy calcareous sandstone	1
15. Prominent dense well-bedded argillaceous limestone with lamellibranchs and brachiopods	2
14. Argillaceous limestones with thin shales	43
13. Recrystallized limestone, thin fossiliferous calcareous clays and thin calcareous sandstone	6
12. Calcareous mudstones and shales with a few fossils near the top	130
11. Prominent flaggy, cross-bedded calcareous sandstone often displaying slump structures	10

*The total thickness of beds 29-32 is 67 feet five miles to the east.

10. Calcareous shales	20
9. Flaggy sandy limestone	1
8. Calcareous shales	10
7. Flaggy, cross-bedded calcareous sandstone	10
6. Calcareous shales	40
5. Flaggy, cross-bedded calcareous sandstone	15
4. Calcareous shales	15
3. Argillaceous limestones with calcareous shales interbedded with thin sandy beds in the south	100
2. Crystalline fossiliferous limestone, thicker and sandy towards the south	2
1. Argillaceous limestone (thickness as exposed in the south-west)	60
	<hr/>
	802

Beds 10 to 41 were measured in the main Seir hills, and beds 1 to 9 in the foothills to the west.

The addition of the measured sections reveals a thickness of nearly 950 feet and if the unexposed sections of the lower parts of the group are taken into consideration, a thickness of over 1,000 feet can be deduced for the Seir Limestones.

The rocks of this group are mostly of various tints of grey or brownish-grey, the re-crystallized limestones weathering to yellowish brown and the sandy horizons to a distinct reddish-brown. The sandy beds are often finely laminated and cross-bedded. Deposition of the sandy beds occurred in the littoral zone, as is indicated by the occurrence of fossilized vegetable matter in associated beds both in the north at Galgalligambo and in the south at Tossidi. Under the microscope the sandy rocks display a varying content of sub-angular clastic grains, consisting of quartz, felspar, tourmaline and occasional muscovite and chlorite in a fine-grained calcitic matrix. Calcite is also present as small rounded detrital grains. Specimen 16/186, from the eastern part of the southern outcrop at Wilderri, contains a small amount of glaucönite. The brown colour of the rocks is imparted by their ferruginous content, which is relatively high. All variations from calcareous siltstones and sandstones to sandy and silty limestones are encountered.

A buff calcareous shale collected at Tossidi contains a few very small clastic grains, the bulk of the rock being composed of finely divided argillaceous and calcareous matter. A thin section of the oolitic fossiliferous marker horizon mentioned by Ayers (1952, p. 10) is composed of shell fragments and nearly structureless fine-grained dense ooliths, usually rimmed by limonite-rich layers and cemented by crystalline calcite.

From the palaeontological evidence it is suggested that the boundary between the Oxfordian and Kimmeridgian must be somewhere near the top of the Seir Limestones. A prominent horizon (No. 33 in the measured section) has been taken to represent a convenient base for the Kimmeridgian as the bed can be followed for most of the distance along the western slopes of the Seir, Furfurso and Borahra hills.

Numerous ammonite fragments collected at Wilderri and Dussé have been examined by Dr. Arkell and identified as "fragments of the families *Perisphinctidae* (*Perisphinctinae*, and almost certainly *Perisphinctes sensu stricto* and various subgenera) and *Mayaitidae*. One fragment could be *Epimayaites* aff. *lemoini* Spath. Another seems to be a bit of *Prograyiceras* sp. or possibly of a *Dhosaites* sp. Nevertheless, there is not the slightest doubt as to the age of the assemblages, which are substantially the same from both localities. They are Upper Oxfordian, Transversarium Zone". Fossils previously found at the same locality were listed in Ayers (1952, p. 29) as follows:—

Milleporidium somaliense,
Parellelodon egertonianus (Stol.),
P. egertonianus (Stol.) var. *crericostatus* (Stef.),
Pinna stoliczkaia Cox,
Gervillia (*Gervillella*) aff. *aviculoides* Sow.,
Meleagrinnella aff. *ovalis* (Phill.),
Exogyra nana (J. Sow.),
E. vinassai,
Lophagregarea (J. de C. Sow.),
Liostraea sp.,

Pleuromya aff. *solodurinensis* de Lor.,
Ceromyopsis sp. cf. *somaliensis* Weir,
Thracia depressa J. de C. Sow.,
 ? *Myopholas acuticostata* (J. de C. Sowerby),
Bourguetia striata Sow.,
Pseudomelania sp.?,
Nautilus sp.,
 ? *Dhosaites* (cf. "*Macrocephalites*" *rabai* Dacqué),
 ? *Mayaites* sp.,
Perisphinctes (*plicatilis* group),
Belemnopsis tanganensis (Fütt).

Other fossils from Wilderri and Dussé collected during the present survey and identified by Dr. Cox include:—

Grammatodon (*Indogrammatodon*) *irritans* (Hennig),
G. (*Indogrammatodon*) *stockleyi* Cox,
Modiolus (*Inoperna*) *plicatus* J. Sowerby,
Campionectes auritus (Schlotheim) [= *C. lens* (J. de C. Sow.)],
Chlamys (*Radulopecten*) cf. *inaequistrata* (Phillips),
Eopecten cf. *bonjour* (de Loriol),
Lima (*Plagiostoma*) cf. *laeviuscula* (J. Sowerby),
Pseudolimea duplicata (J. de C. Sowerby),
Ostrea (*Liostraea*) *dubiensis* Contejean,
Lopha solitaria (J. de C. Sowerby),
Pinna (*Stegoconcha*) *g.-mülleri* Krenkel,
Astarte n. sp.,
Anisocardia ? sp.,
Protocardia sp.,
Ceratomya excentrica (Roemer),
Ceromyopsis aff. *striata* (d'Orbigny),
Pseudomelania valfinensis (de Loriol),
Ampullospira eudora (d'Orbigny),
Bourguetia saemanni (Oppel),
Harpagodes oceani (Brongniart) ?,
Aporrhais sp.,
Nerinella sp. indet.,
Trochalia depressa (Voltz).

The upper part of the Seir Limestones is mostly unfossiliferous, but the fossils listed below have been collected from it (Ayers, 1952, pp. 24 and 30):—

Ornithella sp. nov.,
Terebratula africana Weir,
T. cf. *bihinensis* Weir,
Bihenithyris barringtoni Muir-Wood,
Mytilus alatus Krum,
Pinna stoliczkaia Cox,
 ? *Trichites suprajurensis* Krum,
Meleagrinella aff. *ovalis* (Phill.),
M. cf. *maltonensis*,
Entolium sp. ? cf. *solidum* Roem.,
Ceratomya concentrica (J. de C. Sowerby),
Belemnopsis tanganensis (Fütt).

The part of the Seir Limestones considered to be of Kimmeridgian age contains (Ayers, 1952, pp. 24 and 30):—

Hydrozoan indet.,
Entolium sp.,
 ? *Ctenostreon* (spines),
Ostrea cf. *costata*,
Pholadomya ragazzi Pant.,
Nerinea sp.,
Belemnopsis tanganensis (Fütt).

Meleagrinnella ? sp. indet. and *Mactromya rugosa* (Roemer) were collected recently from the same beds, the second fossil indicating a Corallian or Kimmeridgian age according to Dr. Cox.

The Seir Limestones can be correlated with the Hamanlei Formation of Ethiopia, and the olive to grey gypsiferous shales of the Gahodleh Shales and the Wanderer Limestone (lower Kimmeridgian) of Somaliland Protectorate are contemporaneous deposits extending to the north. The Oxfordian of Somalia is dated on stratigraphical rather than on palaeontological grounds (Stefanini, 1925, p. 1,064)—a thick series of fragile, grey to bluish, marly beds overlies the Callovian and is in turn overlain by deposits of Sequanian age at Anole and Hural. It is interesting to note that sometimes fossils are restricted to sandy beds that alternate with the marls, and that the prevalence of belemnites invites comparison with the southern exposures of the Seir Limestones. The main rock type deposited in Madagascar during the Argovian was limestone, but in south-west Madagascar coarse ferruginous sandstones with some gypsiferous shales overlying the limestones indicate a marine regression in those parts towards the close of the Argovian.

(f) *The Hereri Shales*

The lower part of this group is best exposed along the Hereri river-course, about three quarters of a mile south of the Mandera-Rahmu road, where soft green gypsiferous shales yield a wide variety of fossils. The road crosses the beds further to the east and at Melka Dakacha the upper part of the group is exposed in the bank of the River Daua as soft gypsiferous shales underlying mainly compact calcareous beds. Poor exposures also occur further south-west at the foot of the Harahra hills. The base of the group is not visible and the succession is complicated by the fault that crosses the Hereri valley so that only an approximate calculation of the thickness can be attempted. It is believed that the beds are possibly about 200 feet in thickness. There is nothing in the exposures that are available to suggest a break in deposition between the Seir Limestones and the Hereri Shales. The gypsiferous shales at Dakacha were confused by Dixey (1948, p. 36) with rocks of the Mandera Series, so leading him to invert the succession, but Ayers (1952, pp. 10-11) described these shales as the Upper Shales of the Limestone Series. The section in the bank of the Daua was also described by Weir (1929, p. 11, Melka Dakka).

The exposed succession of the Hereri Shales was measured along the slopes of the hills extending from Dakacha to the Hereri river:—

	<i>Thickness (feet)</i>
9. Mainly grey argillaceous limestones, becoming soft, shaly and gypsiferous towards the top	20
8. Flaggy, brown or red-brown cross-bedded calcareous siltstone, with numerous oysters and terebratulids ..	5
7. Grey argillaceous limestones with gastropods	30
6. Brown, flaggy sandy limestone, with oysters and terebratulids	2
5. Shales, poorly exposed	15
4. Yellow-brown limestone with shell fragments; often sandy	1
3. Soft, friable, yellow-green gypsiferous shales with thin argillaceous limestones; very fossiliferous	55
2. Massive and compact argillaceous limestone, with oysters and a few other lamellibranchs	1
1. Soft, friable gypsiferous shales	4
	133

The shales of Hereri often contain nodules composed of dense calcareous material, the nodules being usually rounded although some are ovoid or elongate. The shales are almost non-calcareous. Irregular veins of selenite, usually approximately parallel to the bedding, occur in them. The interbedded argillaceous limestone (No. 2 in the measured section) exposed in the river bed displays a perfect set of vertical joints, the outcrop consisting of square blocks of limestone (Plate Ia). This bed is mildly folded along N.W. fold axes.

Under the microscope the shales are seen to contain a high percentage of small sub-angular clastic grains enclosed by a dense, finely divided, feebly calcareous clayey matrix. The flaggy fossiliferous horizon (No. 8 in the measured section) is most distinctive and can be used as a marker horizon over long distances along the strike. The lower fossiliferous part of this horizon is oolitic and often of an unmistakable red-brown colour. The microscope reveals that the red colour is due to numerous nodules and grains of hematite, lined by limonite, which occur with shells and ooliths in a calcareous matrix. Occasional clastic grains occur singly or in clusters in the calcareous clay infillings of fossils.

The foraminifera *Epistomina* sp. and *Cristellaria* sp. occur in the shales, but give no clue to their age. The faunal assemblage collected at Hereri, however, strongly suggests a Kimmeridgian age (Ayers, 1952, pp. 23, 30 and 31):—

?*Thamnosseris gibberosa* Gregory,
Apiocrinus aff. *roissyanus* d'Orbigny (columnals),
Ornithella sp. cf. *humeralis* Roemer,
Terebratula (*Lophrothyris*) *subsella* (Leym.) (= *suprajurensis* Thurm.),
T. cf. *zietenii* de Loriol,
Bihenithyris barringtoni Muir-Wood,
B. weiri Muir-Wood,
Berenicea somalica Dacqué,
Nucula sp.,
Parallelodon egertonianus (Stol.),
Mytilus alatus Krum. (*M. tigrinus* Blandford = *M. jurensis* Roem.),
Modiolus (*Inoperna*) *perplicata* (Etal.),
M. cf. *ungulatus* Young and Bird,
Brachydontes (*Arcomytilus*) *subpectinatus* d'Orbigny,
Pinna sp.,
Oxytoma aff. *expansa* Phill.,
Meleagrinella sp.,
Eopecten aubryi (Douv.),
E. (= *Velata*) sp.,
Radulopecten cf. *erlangeri* Dacq.,
Lima (*Plagiostoma*) *astartina* (?) Thurm.,
Ostrea (*Gryphaea*) *balli* (Stef.)?,
Ostrea sp.,
Astarte ovata W. Smith,
Cypricardia (*Pseudotrapezium*) aff. *cardiformis* Desh.,
Lucina rugosa Roemer,
Ceratomya excentrica (Roem.),
Ceromyopsis sp.,
Ampulella sp.,
Harpagodes (*Pterocera*) aff. *polypoda* Buvignier,
H. cf. *thirriae*,
Nerinea sp.,
N. somaliensis Weir ?,
 cf. *Perisphinctes achilles* d'Orbigny (? = *Lithacoceras kenyaense* Spath),
Belemnites tanganensis (Fütt).

Thamnosseris gibberosa and *Lophrothyris* aff. *subsella* were also reported by Weir from Melka Dakacha (Weir, 1929, p. 11).

The following additional brachiopods were collected during the present survey, and were identified by Dr. Muir-Wood who suggested that they are probably of Kimmeridgian age:—

"*Terebratula*" sp. A, ? nov.,
 "*Terebratula*" *jooraensis* var. *hararensis* Cottreau,
 "*Terebratula*" sp. B, ? nov.,
 "*Terebratula*" cf. *longisinuata* Krumbeck,
Lophrothyris (?) *senilis* Muir-Wood,
 "*Terebratula*" sp. nov.

The "*Terebratula*" sp. B. and the "*Terebratula*" sp. nov. also occur in the Dakacha Limestones and at the junction of the Daua Limestone Series and the Mandera Series.

Lamellibranchs and gastropods collected during the survey and identified by Dr. Cox are in keeping with a Kimmeridgian age:—

Grammatodon (Indogrammatodon) irritans (Hennig),
Modiolus imbricatus J. Sowerby,
Chlamys curvivarans (Dietrich),
Eopecten inaequistriatus (Thurmann),
Exogyra sp. indet.,
Cardium [? *Protocardia*] *bannesium* Contejean,
Ceromyopsis striata (d'Orbigny),
Bourguetia cf. *saemanni* (Oppel),
Harpagodes oceani (Brongniart),
Globularia hemisphaerica (Roemer).

The northern extension of the Hereri shales is apparently represented in Ethiopia by the Uarandab group (Taylor, 1948 A, p. 252) which consists mainly of shale, though there is a lower limestone member. Further north, in Somaliland, they are represented by the Daghani shales (Macfadyen, 1933, p. 28). There is a marked increase in thickness to the north—the thickness in Ethiopia is 500 feet and in Somaliland about 1,200 feet.

This notably argillaceous group in the Jurassic succession of north-eastern Africa is absent, or perhaps not exposed in Somalia. Stefanini (1925, p. 1,065) states that fossiliferous limestones overlying the Sequanian beds there may be of Kimmeridgian age, though he also states they may possibly be Portlandian. In the Mombasa-Kwale area of coastal Kenya the Kimmeridgian stage is represented by the Changamwe Shales and in Madagascar the Kimmeridgian consists mainly of marls and limestones.

(g) *The Dakacha Limestones*

The Dakacha Limestones form a prominent continuous ridge that extends from Melka Dakacha to the Raiya hills. The sediments of the group are easily distinguished from the overlying Mander Series by the sharp difference in lithology, colour and topographical prominence. On aerial photographs the numerous ant-hills, present everywhere on the Daua Limestone Series, are seen to terminate abruptly when the junction with the Mander Series is reached. The southern extension of the Dakacha Limestones occurs along the west flank of the Raiya hills and forms slight elevations in the relief. Here the beds are often masked by calcrete.

The Dakacha Limestones are also exposed along the western flank of the Hegalu horst in the eastern part of the area, but exposures are generally poor. Here the base of the succession is not exposed and it is evident that the thickness is greater than further west, which again suggests a gradual increase in thickness of the sediments to the east.

The succession of the Dakacha Limestones was measured in the hills immediately south and south-west of Melka Dakacha:—

	<i>Thickness (feet)</i>
17. Compact grey argillaceous limestones with shales towards the top	10
16. Calcareous shales and argillaceous limestone with some yellow and red thin calcareous mudstone bands ..	c.50
15. Dark grey fine-grained limestone	4
14. Calcareous shales	15
13. Grey compact argillaceous limestone	4
12. Mainly calcareous shales	15
11. Grey compact argillaceous limestone	4
10. Calcareous shales with thin argillaceous limestones containing gastropods	10
9. Compact grey argillaceous limestone	2
8. Calcareous shales	10
7. Grey oolitic limestone with oysters	3
6. Calcareous shales	20
5. Dark grey limestone	5
4. Grey argillaceous limestones	20
3. Compact grey argillaceous limestones	15
2. Compact grey argillaceous limestones with irregular yellow patches; some thin shaly bands	110
1. Brown oolitic limestone	1
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The characteristic rock type of this succession, the compact grey argillaceous limestone, often contains numerous internal casts of big gastropods. Under the microscope such rocks are seen to be extremely dense and to contain small sub-angular clastic grains scattered throughout them. Occasional patches of coarsely crystalline calcite occur where sections cut through fossil remains. Large irregular patches and veins of limonite discolour the rocks and give rise to the yellow patches on weathered surfaces.

A brown circular patch, a few yards across, occurs in these sediments above Melka Dakacha. On closer examination the rock (16/123) was found to consist of coarsely crystalline dolomitic limestone, brown in colour with numerous white and dark grey irregular spots. Small cavities, lined by coarsely crystalline calcite, occur throughout the rock. The microscope reveals that the difference in colour and texture is due to dolomitization of the limestone. The rock consists of a mosaic of patches of coarsely crystalline and fine-grained carbonate, the crystalline carbonate displaying typical rhombohedral crystals indicating dolomite. The recrystallization of the carbonate has the expected effect of the exclusion of ferruginous material which segregates to crystal boundaries, but also occurs within crystals as small inclusions with linear arrangement.

The Dakacha Limestones are also dolomitized below the unconformable junction with the Marehan Series. The grey uniform argillaceous limestones alter as the junction is neared and become darker in colour with irregular light-coloured patches, often displaying small nodules of crystalline calcite, and on the whole have almost no reaction with cold hydrochloric acid. The mosaic of rhombohedral carbonate crystals with numerous inclusions contains patchily distributed small clastic grains and limonite, the distribution of the latter sometimes revealing the original shapes of oolites and shell fragments destroyed by the recrystallization of the rocks. Small cavities in the rocks, usually lined by limonite-stained calcite, are indicative of the decrease in volume resulting from dolomitization.

Oolites are abundant in the lower part of the Jurassic succession, but during Oxfordian and Kimmeridgian times oolitic beds were not often deposited, with the result that such horizons are useful markers. Although poorly developed and thin, they have been found to be remarkably constant along the strike. The oolitic horizon in the Dakacha Limestones (No. 7 in the measured section; specimen 16/48) is composed of oolites, with occasional faint concentric structure though they are mostly dense and apparently structureless, cemented by limonitic carbonate containing angular clastic grains of feldspar and quartz. Fragments of fossils are frequent in the thin section and include crinoid columnals.

Colonial corals are abundant in the beds immediately overlying the Hereri Shales in the Harahra area and serve to define the stratigraphical position in that vicinity.

During the present survey numerous fossils were collected from the shaly part of the uppermost beds of the Dakacha Limestones (No. 17 in the measured section). The fauna that marks the close of the sedimentation of the Daua Limestone Series is abundant and varied, the assemblage consisting mainly of numerous terebratulids, crinoid columnals (*Apiocrinus* sp.), and mussels (*Mytilus* sp.). The same faunal assemblage occurs immediately below the Daua Limestone Series-Mandera Series junction at Hegalu, more than thirty miles south of Melka Dakacha.

The fauna of the Dakacha Limestones was listed in Ayers (1952, pp. 23, 24 and 31) as follows:—

- Dermosmilia* sp. cf. *corymbosa* Koby,
- "*Cidaris*" sp.,
- Ornithella* sp. (?),
- Ornithellids; (Hegalu),
- Terebratula* sp. nov.; (Hegalu),
- T. (Lophrothyris) subsella* Leym.,
- Bihenithyris barringtoni* Muir-Wood (?),
- Modiolus (Inoperna) perplicata* (Etal.),
- M. subangustissimus* Dacqué,
- Brachydontes subpectinatus* d'Orb.,
- Camptonectes* cf. *viridunensis* (Buv.),
- Plagiostoma* cf. *sublaeviuscula* (J. Sow.); (Hegalu),
- Lima (Plagiostoma)* sp.,
- Anomia* sp.,

Gryphaea sp.,
 ? *Opis michelina* Buvignier,
Ceratomya excentrica (Roem.),
Pholadomya sp. (Hegalu hills),
Ampulella sp.,
Harpagodes sp.

In addition *Liostrea* sp. was reported by Weir (1929, p. 15). Dr. Cox compared the *Harpagodes* with *H. oceani* (Brongniart), which is a Kimmeridgian species. Professor Douglas (Ayers, 1952, p. 31) considered that the ornithellids and the *Terebratula* sp. nov. from Hegalu have an upper Jurassic-lower Cretaceous aspect and, as a result, he did not exclude the possibility that these beds are post-Kimmeridgian.

Confirmation of a Kimmeridgian age was found in the following fossils, identified by Drs. Cox and Muir-Wood, collected during the present survey:—

Somalirhynchia hadramautensis (Stefanini),
S. stefanii Weir var.,
 "Terebratula" sp. nov.,
Modiolus virgulinus (Étallon),
Trigonia stefanii Venzo,
Chlamys curvivarans (Dietrich),
Ctenostreon proscideum (J. de C. Sowerby),
Ostrea (Liostrea) cf. *contejean* Étallon,
Lopha gregarea (J. Sowerby),
Pteria sp. nov.,
Quenstedtia sp. nov.,
Eocallista ? sp.,
Protocardia sp.,
Mactromya rugosa (Roemer),
Pholadomya hemicardia (Roemer),
Ampullospira sp.,
Harpagodes oceani (Brongniart),
Trochalia depressa (Voltz),
Globularia amata (d'Orbigny),
G. hemisphaerica (Roemer),
G. phasianelloides (d'Orbigny),
Acteonina ? sp. indet.

On the present mapping the beds are regarded as probably bridging the uppermost Kimmeridgian and the lowest part of the Tithonian.

Ayers (1952, p. 11) ascribed a thickness of 520 feet to his Upper Limestones, of which the Dakacha Limestones form the upper part, and although this thickness includes part of the Hereri Shales of the present report, it is thought to be exaggerated, the true thickness of the Dakacha Limestones being in the region of 300 feet.

Throughout the outcrop the sediments of Kimmeridgian age dip at approximately $1\frac{1}{2}^\circ$ to the south-east. They are affected along the Harahra hills and east of the Furfurso hills by faults. The appearance of inliers of the Dakacha Limestones east of the Daua Limestone Series-Mandera Series junction north-east of Amingure probably indicates a mild anticlinal fold in that vicinity.

The Dakacha Limestones can be correlated with the Gabredare Formation in Ethiopia, a series of alternating limestones and marly limestones exceeding 400 feet in thickness (Taylor, 1948 A, p. 253). These beds are dated as Kimmeridgian-Portlandian and aid the suggestion that the Dakacha Limestones may extend into the Tithonian. The Gawan Limestone of Somaliland Protectorate may correspond in part with the Dakacha Limestones. Macfadyen (1933, p. 28) considered that the Gawan Limestones extended from the upper Kimmeridgian to the uppermost Jurassic, but more recent work (Somaliland Oil Exploration Co. Ltd., 1954, p. 13) suggests that the upper Kimmeridgian is missing and that the Gawan Limestones are Portlandian. It is possible that, if there is lateral variation the upper portion of the Daghani Shales may represent the Dakacha Limestones in part. Again an increase in thickness as one goes northwards is evident, the Gabredarre Formation being 400 feet, and the Gawan Limestone 800 feet. In Somalia, according to Stefanini (1925, pp. 1064-1065), the limestones containing crinoids and corals overlying the Sequanian may be of either

Plate I



(a) Jointing and minor folding in a thin limestone of the Hereri shale group exposed in the bed of the Hereri river, half a mile south of the Mandera-Rahmu road.



(b) Remnants of the 10 metre terrace in the Daua valley, north-east of Mandera.

Plate II

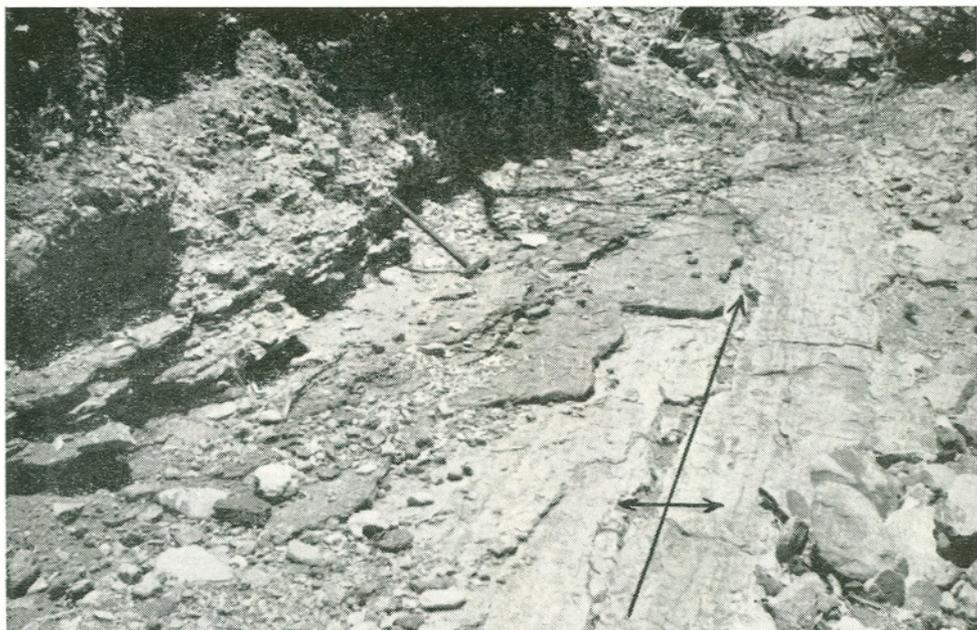


(a) Light grey calcareous shales of the uppermost part of the Daua Limestone Series comfortably overlain by brown silty sandstones of the Mandera Series, three miles north-east of Melka Dakacha.

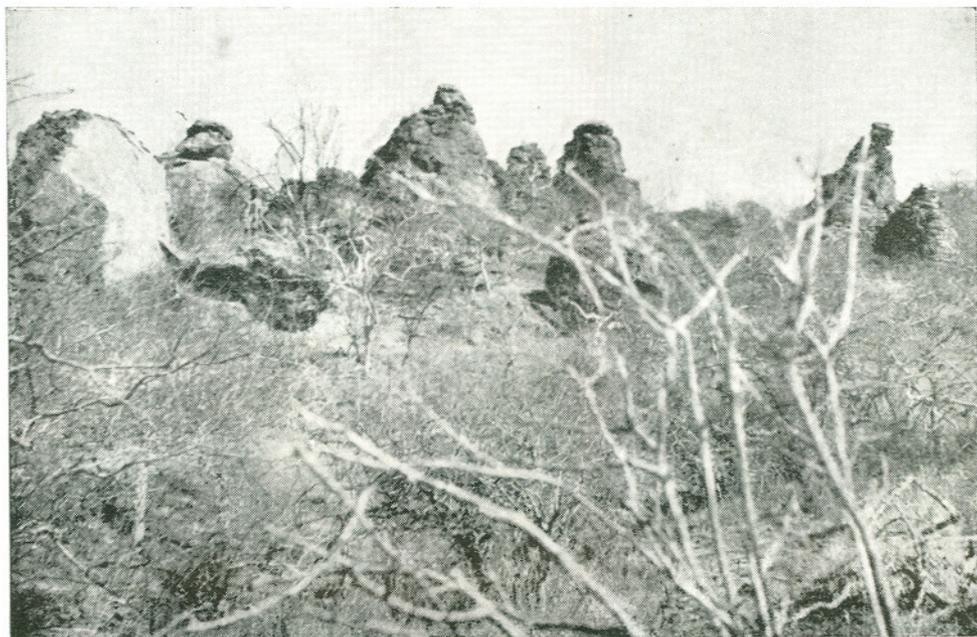


(b) Tors of massive sandstone below the Jirma Limestone of the Mandera Series, one mile west of Jirma hill.

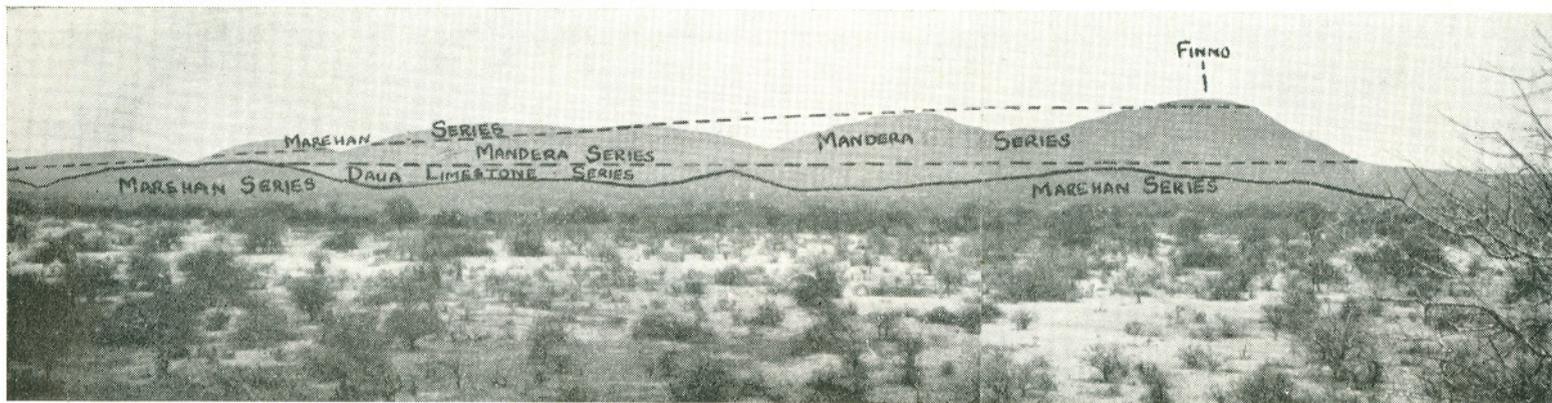
Plate III



(a) Folded buff siltstones of the Mander Series unconformably overlain by darker undisturbed silty mudstones of the Marehan Series in the Sarego area.



(b) Sandstone tors, lower sandstone horizon, Danissa Beds, Sarego.



(a) The Hegalu hills viewed from Bar Hafura. Beds of the Marehan Series forming the low hills in middle distance are thrown down by the western Hegalu fault. The angle of unconformity between the capping of Marehan Series beds on the main hills and the Mandara and Daua Limestone Series is clearly shown.



(b) Minor folding in the Seir Limestones, three miles south-east of Umbiso. The fold axes have north-east-south-west trend.

Plate V

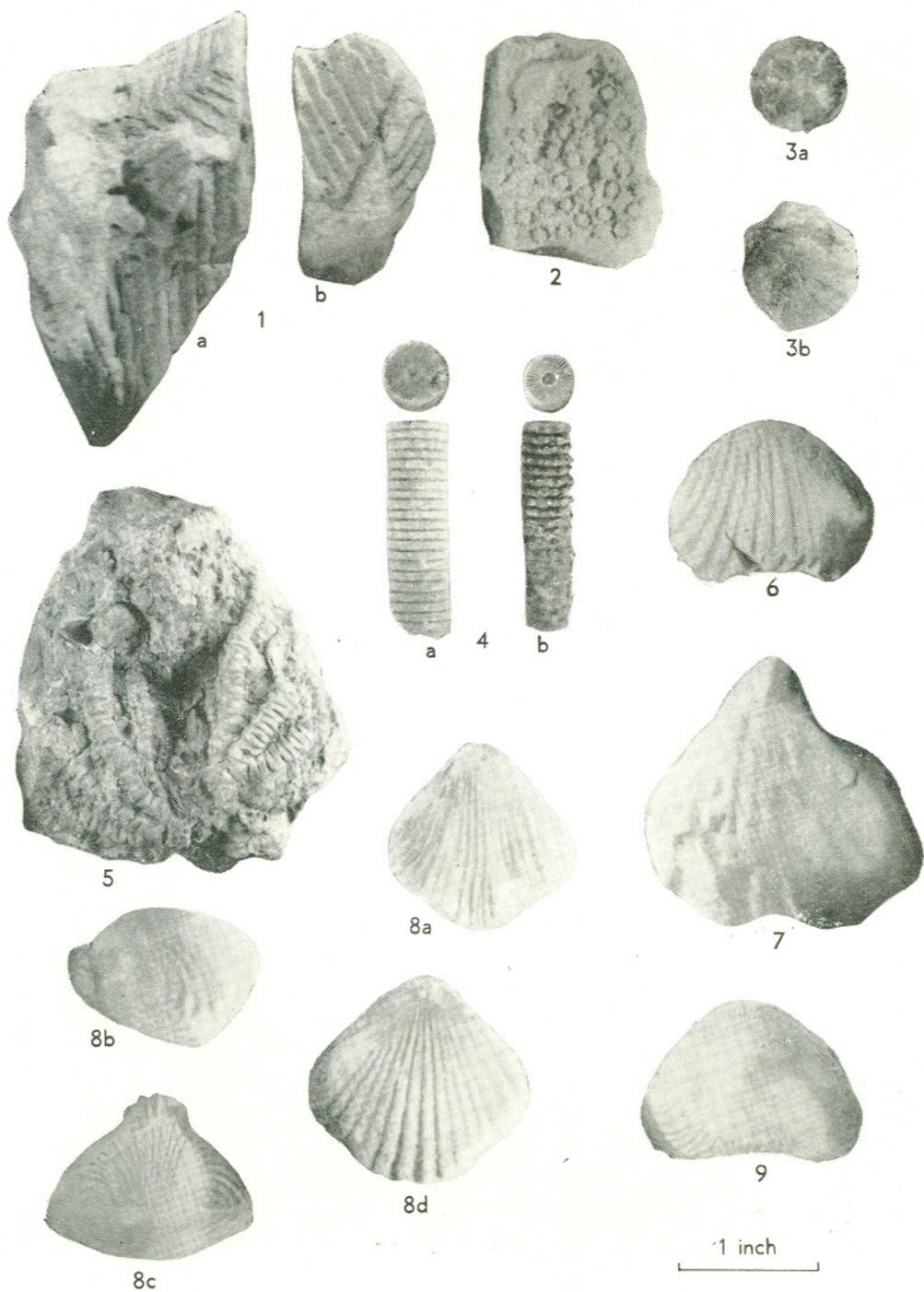


Plate VI

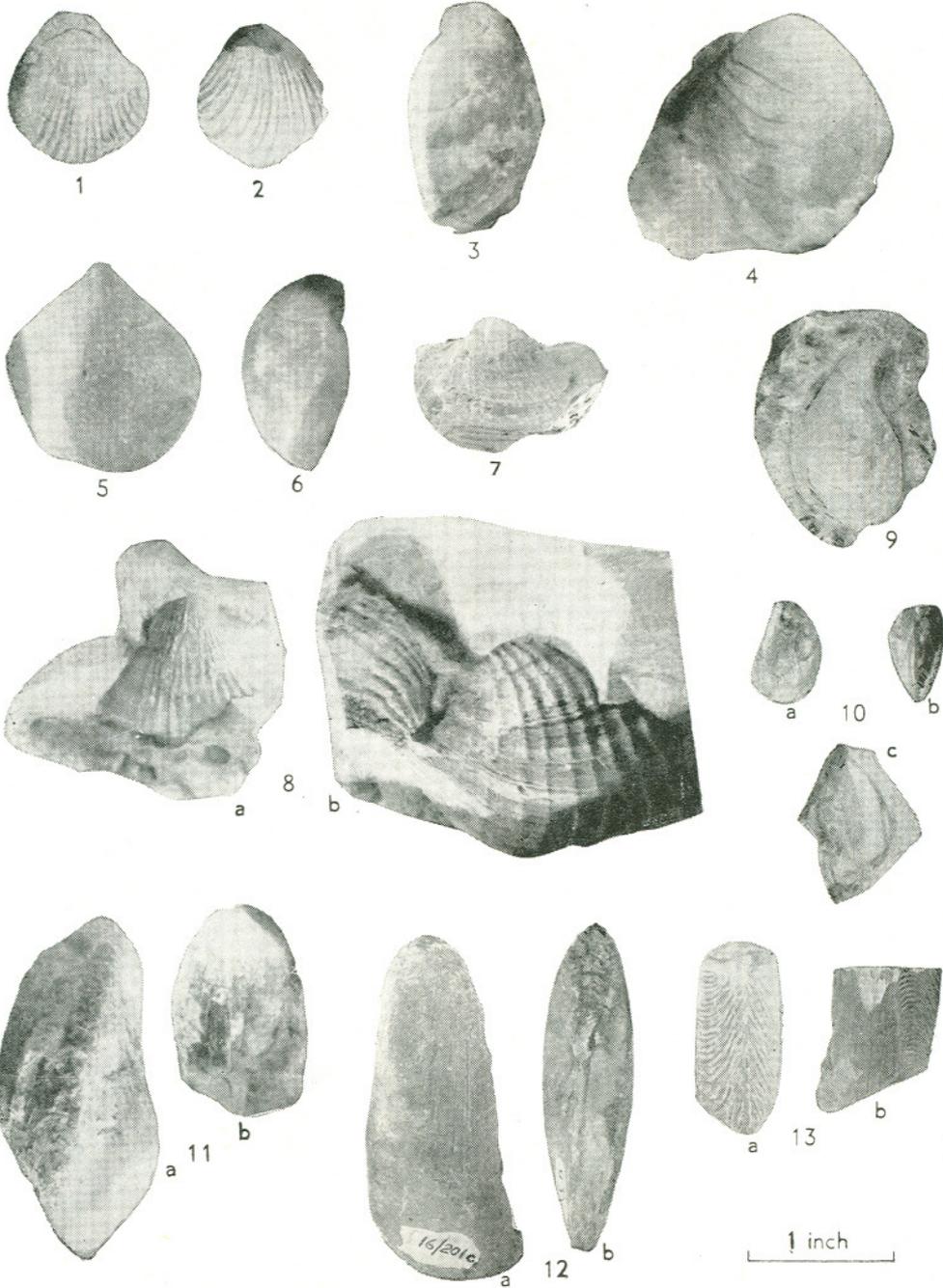
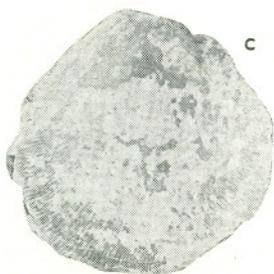
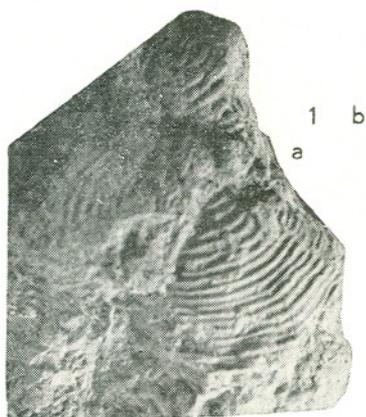


Plate VII



1 inch

Plate VIII

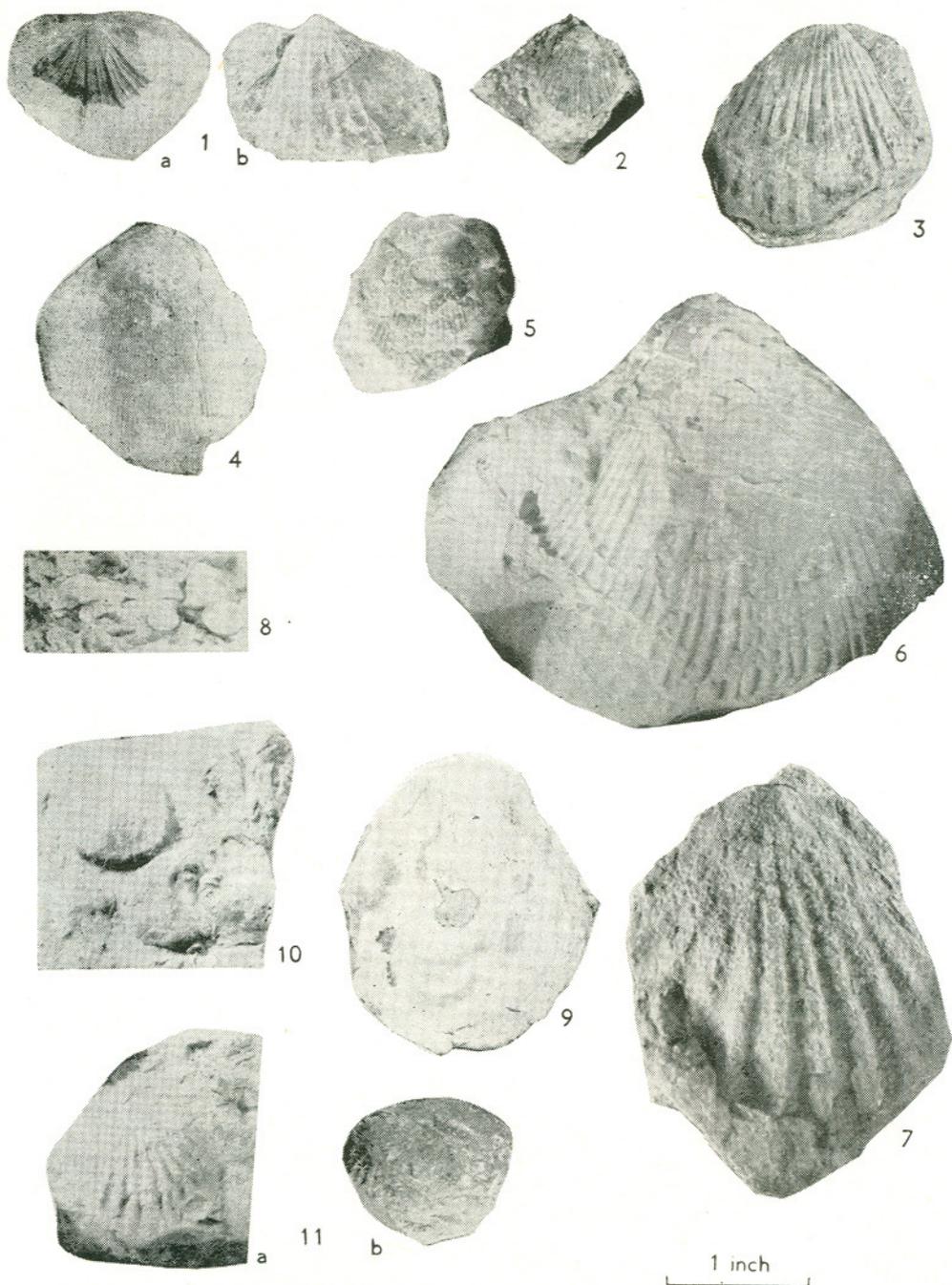


Plate IX

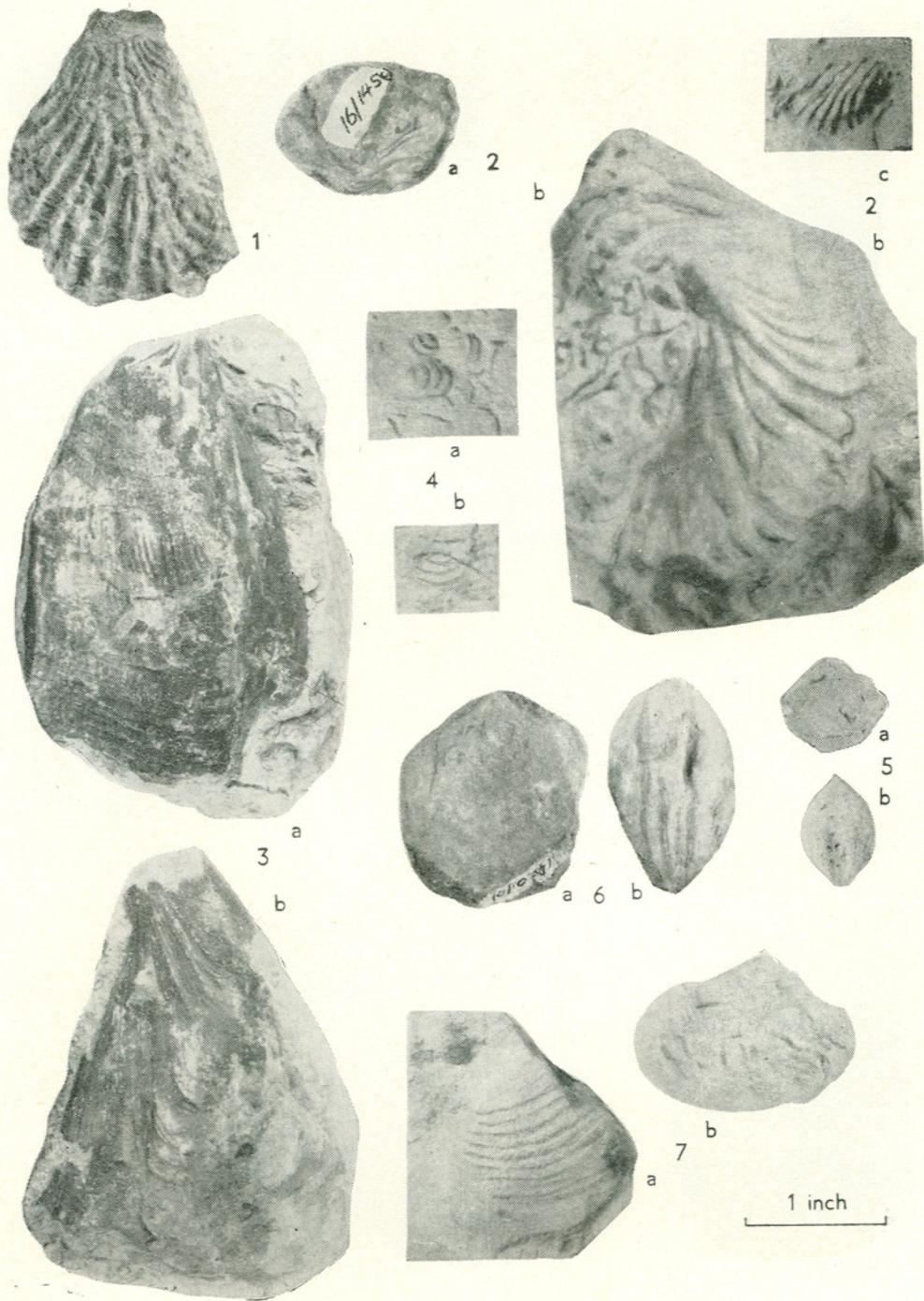


Plate X

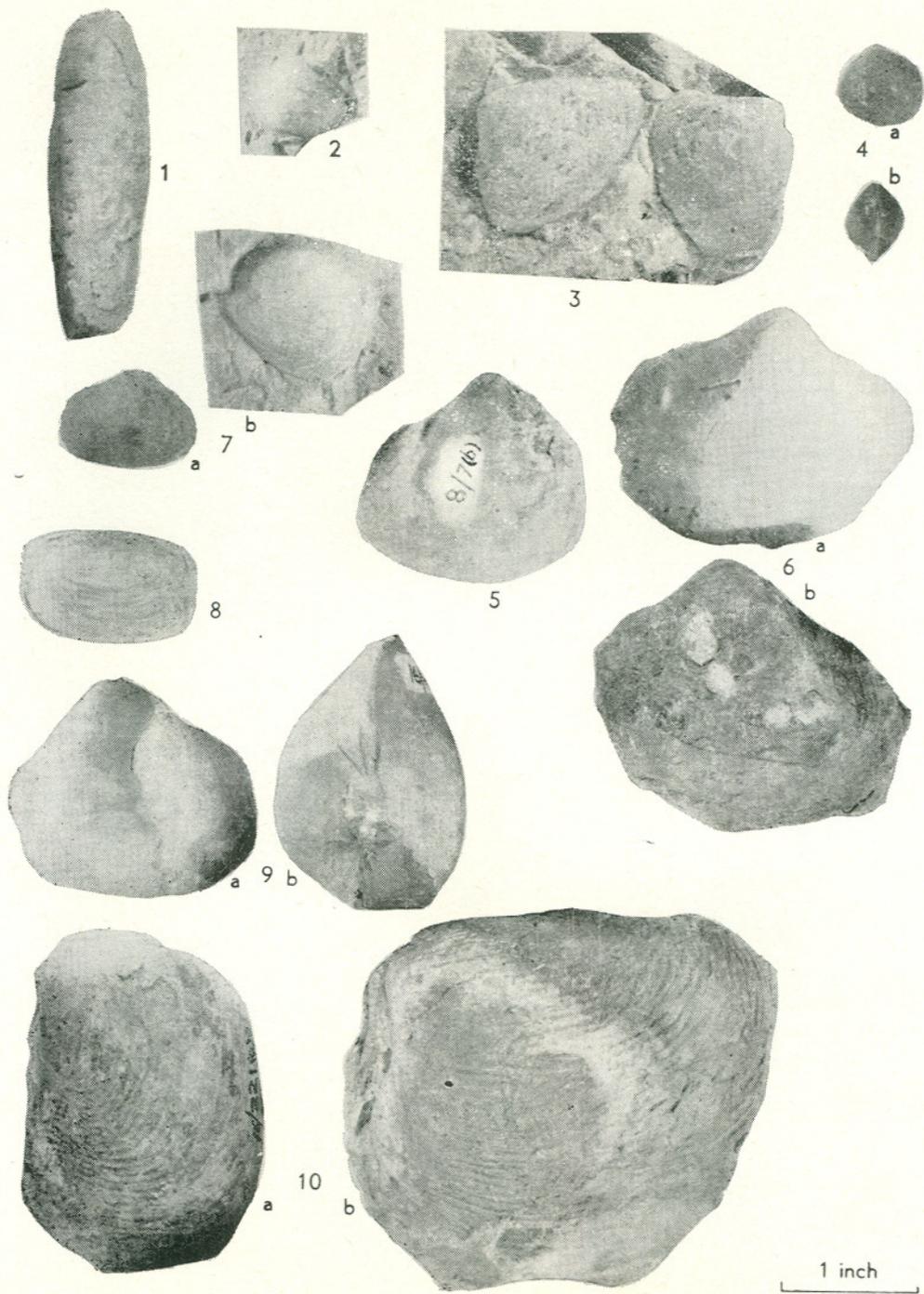


Plate XI

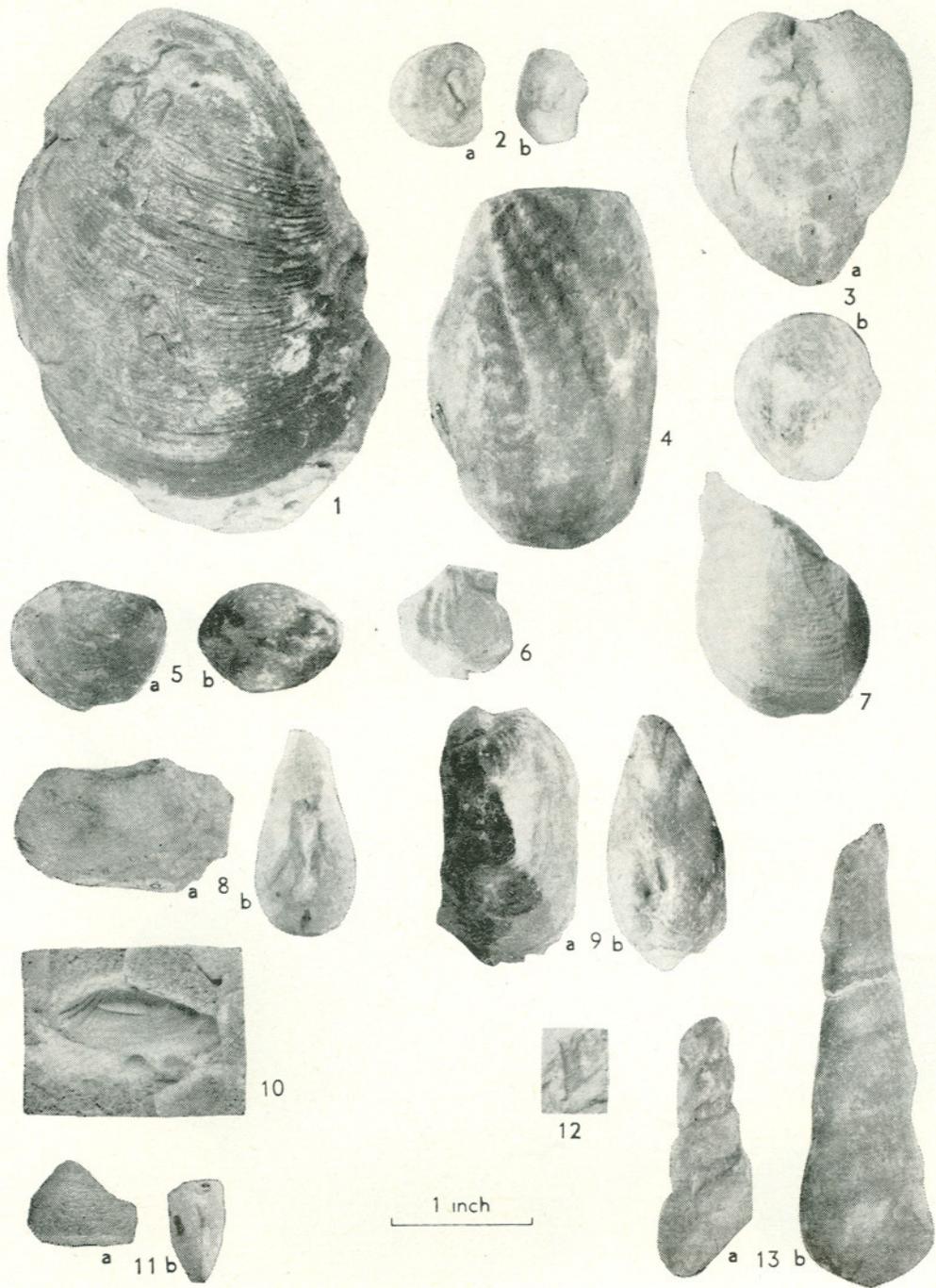


Plate XII



EXPLANATION OF PLATES V - XII

PLATE V

- 1.—(a and b) *Zamites* sp., Danissa Beds. Locality—Figfirya.
2. Coral, Muddo Erri Limestones. Locality—Muddo Erri.
- 3.—(a and b) Echinoids, Muddo Erri Limestones. Locality—Kulong.
- 4.—(a and b) Crinoid columnals, Dakacha Limestones. Locality—three miles N.E. of Dakacha.
5. Crinoid, Seir Limestones. Locality—Dussé.
6. *Septirhynchia pulchra* var. Muir-Wood, Muddo Erri Limestones. Locality—Kulong.
7. *Septirhynchia* cf. *azaisi* (Cottreau), Muddo Erri Limestones. Locality—Kulong.
- 8.—(a to d) *Somalirhynchia africana* Weir, Rahmu Shales. Locality—5½ miles S.S.W. of Rahmu.
9. *Somalirhynchia africana mesoloba* Muir-Wood, Rahmu Shales. Locality—5½ miles S.S.W. of Rahmu.

PLATE VI

1. *Somalirhynchia somalica* (Dacqué), Rukesa Shales. Locality—17 miles west of Rahmu.
2. *S. stefaninii* var. Weir, Rukesa Shales. Locality—17 miles west of Rahmu.
3. *Terebratula suprajurensis* Thurman, Rahmu Shales. Locality—5½ miles S.S.W. of Rahmu.
4. "*Terebratula*" sp. nov., Hereri Shales. Locality—Hereri river crossing.
5. *Pseudoglossothyris sulcata* Muir-Wood, Muddo Erri Limestones. Locality—Kulong.
6. *Somalithyris bihendulensis* Muir-Wood, Rahmu Shales. Locality—5½ miles S.S.W. of Rahmu.
7. *Grammatodon (Indogrammatodon) irritans* Hennig, Hereri Shales. Locality—Hereri river crossing.
- 8.—(a and b) *G. (Indogrammatodon) stockleyi* Cox, Seir Limestones. Locality—Wilderri.
9. *Brachidontes (Arcomytilus)* sp., Muddo Erri Limestones. Locality—Kulong.
10. *B. (Arcomytilus) asper*. J. Sowerby: (a) and (b) Muddo Erri Limestones. Locality—Kulong.
(c) Murri Limestones. Locality—Melka Biini.
- 11.—(a and b) *Modiolus imbricatus* J. Sowerby, Hereri Shales. Locality—Hereri river crossing.
- 12.—(a and b) *M. virgulinus* (Étallon) Dakacha Limestones. Locality—three miles N.E. of Melka Dakacha.
- 13.—(a and b) *M. (Inoperna) perplicatus* (Étallon) fragments, Dakacha Limestones. Locality—three miles N.E. of Melka Dakacha.

PLATE VII

1. *Trigonia* sp. nov. (= *T. brevicostata* Venzo non Kitchin), Danissa Beds. Localities—(a) Bur Hafura, (b) Odda.
2. *T. stefaninii* Venzo, Dakacha Limestone, Locality—three miles N.E. of Melka Dakacha.
- 3.—(a to e) *Camptonectes aurites* (Schlotheim) (= *C. lens* (J. de C. Sowerby)), Seir Limestones. Locality—Dussé.
4. *Chlamys (Radulopecten)* cf. *inaequistriata* (Phillips), Seir Limestones. Locality—Dussé.
5. *C. curviviarians* (Dietrich), Hereri Shales. Locality—Hereri river crossing.
6. *Chlamys* sp. indet. Seir Limestones. Locality—Wilderri.
7. *Eopecten abjectus* (Phillips), Rukesa Shales. Locality—11 miles west of Rahmu.

PLATE VIII

1. *Eopecten aubryi* (Douvillé); (a) Rukesa Shales. Locality—17 miles west of Rahmu. (b) Muddo Erri Limestones. Locality—Kulong.
2. *E.* cf. *bonjourii* (de Loriol). Seir Limestones. Locality—Wilderri.
3. *Lima (Plagiostoma)* cf. *schardtii* de Loriol, Muddo Erri Limestones. Locality—Kulong.
4. *L. (Plagiostoma)* sp. nov. ? Murri Limestones. Locality—Melka Biini.
5. *L. (Plagiostoma)* cf. *complanata* Laube, Muddo Erri Limestones. Locality—Kulong.
6. *L. (Plagiostoma)* cf. *laeviuscula* (J. Sowerby), Seir Limestones. Locality—Kulong.
7. *Ctenostreon proscideum* (J. de C. Sowerby), Dakacha Limestones. Locality—Melka Dakacha.
8. *Ostrea (Catynula)* cf. *ancliffensis* Cox and Arkell, Rukesa Shales. Locality—11 miles west of Rahmu.
9. *O. (Liostrea)* sp. indet., Murri Limestones. Locality—Melka Biini.
10. *Exogyra* sp. indet. Seir Limestones. Locality—Wilderri.
11. *Eligmus rollandi* Douvillé; (a) Rukesa Shales, Locality—15 miles west of Rahmu. (b) Muddo Erri Limestones. Locality—Kulong.

PLATE IX

1. *Lopha gregarea* (J. Sowerby), Dakacha Limestones. Locality—three miles N.E. of Melka Dakacha.
- 2.—(a to c) *L. solitaria* (J. de C. Sowerby), Weir Limestones. Locality—Wilderri.
- 3.—(a and b) *Pinna (Stegoconcha) g-mülleri* Krenkel, Seir Limestones. Locality—Dussé.
- 4.—(a and b) *Astarte* sp. nov. Seir Limestones. Locality—Dussé.
- 5.—(a and b) *Anisocardia* ? sp. Seir Limestones. Locality—Wilderri.
- 6.—(a and b) *Lucina* sp. Muddo Erri Limestones. Locality—Kulong.
7. *Corbis lajoyei* d'Archiac, (a) Muddo Erri Limestones. Locality—Kulong. (b) Rukesa Shales. Locality—15 miles west of Rahmu.

PLATE X

1. *Quenstedtia* sp. nov. Dakacha Limestones. Locality—Junction, Figfiry.
2. *Eocallista* ? sp., Mander Series. Locality—Amingure.
3. "*Eocallista*" *merlai* Venzo, Mander Series. Locality—Matasafara.
- 4.—(a and b) *Protocardia* sp., Seir Limestones. Locality—Dussé.
5. *Protocardia* sp., Rukesa Shales. Locality—17 miles west of Rahmu.
- 6.—(a and b) *Cardium* (? *Protocardia*) *bannesium* Contejean, Hereri Shales. Locality—Hereri river crossing.
- 7.—(a and b) *Mactromya aequalis* Agassiz, Muddo Erri Limestones. Locality—Kulong.
8. *M. rugosa* (Roemer), Dakacha Limestones. Locality—three miles N.E. of Melka Dakacha.
- 9.—(a and b) *Ceratomya concentrica* (J. de C. Sowerby), Muddo Erri Limestones. Locality—Kulong.
- 10.—(a and b) *C. excentrica* (Roemer), Hereri Shales. Locality—Hereri river crossing.

PLATE XI

1. *Ceratomya excentrica* (Roemer) Seir Limestones. Locality—Dussé.
- 2.—(a and b) *Ceromyopsis killiani* Rollier, Muddo Erri Limestones. Locality—Kulong.
- 3.—(a and b) *C. aff. striata* (d'Orbigny), Hereri Shales. Locality—Hereri river crossing.
4. *Pholadomya* sp., Muddo Erri Limestones. Locality—Kulong.
- 5.—(a and b) *P. hemicardia* Roemer, Dakacha Limestones. Locality—Hegalu hills.
6. *P. lyrata* J. de C. Sowerby, Rukesa Shales. Locality—west of Melka Biini.
7. *P. inornata* J. de C. Sowerby, Rukesa Shales. Locality—17 miles west of Rahmu.
- 8.—(a and b) *P. ovalis* (J. Sowerby), Muddo Erri Limestones. Locality—Kulong.
- 9.—(a and b) *Homomya* sp. nov., Rahmu Shales. Locality—5½ miles S.S.W. of Rahmu.
10. *Myopholas* sp. nov. cast, Mander Series. Locality—Matasafara.
- 11.—(a and b) *Cercomya* ? sp. nov., Rukesa Shales. Locality—West of Melka Biini.
12. *Pseudomelania* sp., Seir Limestones. Locality—Dussé.
- 13.—(a and b) *P. valfinensis* (de Loriol), Seir Limestones. Locality—Wilderri.

PLATE XII

- 1.—(a and b) *Ampullospira eudora* (d'Orbigny), Seir Limestones. Locality—Dussé.
- 2.—(a and b) *Bourguetia saemanni* (Opell), Seir Limestones. Localities—Dussé and Wilderri.
- 3.—(a to c) *Harpagodes oceani* (Brongniart), Dakacha Limestones. Locality—Junction, Figfiry.
4. *Globularia hemisphaerica* (Roemer), Dakacha Limestones. Localities—(a) Junction, Figfiry. (b) three miles N.E. of Melka Dakacha.
5. *G. phasianelloides* (d'Orbigny), Dakacha Limestones. Locality—two miles S.W. of Melka Dakacha.
6. *Paracnoceras* sp. nov., Rukesa Shales. Locality—Melka Rukesa.

Kimmeridgian or Portlandian age, and may accordingly be the equivalent of the Dakacha Limestones. In the Mombasa area of Kenya presumably the upper part of the Changamwe shales is the equivalent of the lower part of the Dakacha Limestones. There, however, there are no Jurassic beds of post-Kimmeridgian age (Caswell, 1953, p. 18; 1956, p. 19). In Tanganyika the Tendaguru Beds, a series of sandstones, silts and clays laid down under alternating marine and estuarine conditions, and noted for the large and abundant saurian remains they yield, are of Upper Jurassic to Lower Cretaceous age, and it appears that the *Trigonia smeei* bed is the equivalent of the Dakacha Limestones (Teale, 1936, pp. 21-22; Wade, 1937, pp. 53-55; Aitken, 1954).

(2) THE MANDERA SERIES

The name "Mandera Series" was adopted by Dixey (1948, p. 84) to distinguish the sandstones, silty shales, mudstones and thin dolomitic limestones that occupy the extreme north-east corner of Kenya. He regarded the series as earlier in age than the Daua Limestone Series, agreeing with the conclusions of Italian geologists who had correlated the beds with the Lugh Group of Somalia. The correlation was based on mineralogical and lithological similarity, however, and cannot be entertained on stratigraphical grounds. Ayers (1952, p. 15) postulated that the Mandera Series passed laterally into the Marehan Series, no doubt being guided to this conclusion by the increase in sandstones and concomitant decrease in calcareous sediments in the Mandera Series to the south-west, and perhaps misled by the remarkable lithological similarity between the lower parts of the two series. Ayers accordingly extended to the north the unconformity between the Daua Limestone Series and the Marehan Series along the foot of the Raiya hills, making it coincide with the base of the Mandera Series. The relationship as now mapped can readily be seen in Fig. 3. The Mandera Series is the upper part of the Jurassic System of north-east Kenya and follows the Daua Limestone Series conformably, both series being overlain unconformably by rocks of the Marehan Series.

The Mandera Series contains thin but remarkably persistent dolomitic limestones that are of assistance as marker horizons. The most distinctive limestone bands were named during the present survey and divide the series into six parts. Considerable lateral variation in thickness and lithology, especially in the lower part of the succession, characterizes the non-calcareous strata. The generalised sequence is as follows:—

Finaguba Beds	Finaguba Limestone
	Shales, siltstones, sandstones and marls
Bur Gawse Beds	Bur Gawse Limestone
	Shales and sandstones
Jirma Beds	Jirma Limestone
	Marls, shales and sandstones
Gingo Beds	Gingo Dolomite
	Marls and sandstones
Guediye Beds	Guediye Limestones
	Sandstones, siltstones shales, marls and thin limestones
Amingure Beds	Amingure Limestone
	Siltstone, shales, marls, sandstones and thin limestones

The thinning of the limestones towards the edge of the basin is unmistakable in the Hegalu hills. In the north-eastern part of the hills in Somalia, limestones, although relatively thin, are much in evidence and mainly occur interbedded with green shales. To the south-west, the limestone horizons are difficult to find because they have thinned out to a few inches, while the shales have given way to coarse siltstones, closely resembling rocks of the Marehan Series. It is significant, however, that most of the siltstones and sandstones of the Mandera Series have at least a small content of glauconite, a mineral that was not encountered in any of the thin sections of the Marehan Series examined.

Apart from thin finely laminated flaggy beds nearly all the sandstones and siltstones of the series are ripple-marked, but ripple-marks in the limestones are restricted to silty varieties. Cross-bedding occurs mainly in the sandstones while fine cross-ripple laminations are developed locally in rocks containing interference ripple-marks. Graded bedding is commonly encountered throughout the succession but is best developed in the laminated flaggy siltstones and fine-grained sandstones. Slumping occurs on a much larger scale in the Mandera Series than in the underlying Daua Limestone Series and in parts may be due to the conversion of anhydrite to gypsum. Flaggy beds nearly always display manganiferous dendritic markings.

The Mandera Series is unfossiliferous for most of its thickness but three fossil-bearing zones are known; the upper two are thin beds while the lower zone includes at least 50 feet of the lowermost beds of the succession. Venzo (1948, p. 117) described the uppermost horizon, which is prolifically fossiliferous near the top of the series (Finaguba Beds) near Mandera and the middle thin fossiliferous horizon (Gudediye Beds) was discovered during the present survey at the foot of the hill at Melka Bila and along the base of the Gingo hills.

The regional dip of the series is approximately 1° to the E.S.E. and, in harmony with the Daua Limestone Series, small gentle folds plunging to the S.E. are displayed in numerous localities, providing anomalous dips.

There is considerable lateral variation in the basal beds of the series, extending from the Amingure area to north-east of Melka Dakacha. The discontinuous exposures in the Amingure area indicate a transition from the conditions in which the upper Daua Limestones were laid down to those of Mandera Series times. A foretaste of the oncoming regression of the sea is provided by thin red and yellowish clayey intercalations within the uppermost limestones of the Daua succession, which becomes sandy towards the top, so that the rocks have a spotted appearance. The limestone also becomes lighter in colour, and eventually grades into a calcareous sandstone. The overlying yellowish green clay contains a thin sugary sandstone band and grades into a fossiliferous marl which is topped by a thin brown sandy limestone. The superficial cover of Pleistocene limestones and gypsum in the vicinity of Amingure masks much of the Mandera Series, but the sequence described above resting on the calcareous sandstone at the top of the Dakacha Limestones is approximately 35 feet thick.

Further to the north the section described by Ayers (1952, p. 12, top) occurs where shales, marls and a sandstone overlie the upper Dakacha Limestones conformably. North-east of Melka Dakacha the junction between the two series is most striking. The base of the Mandera Series is a reddish brown cross-bedded sandstone of which at least 40 feet is exposed, overlying highly fossiliferous light grey calcareous shales of the Dakacha Limestones (Plate IIa). This abrupt lithological change indicates a break in the normal course of deposition, but it is clear that there was no erosion of the Dakacha sediments. At no locality along the junction is there any suggestion of an angular relation between the dips of the two sets of beds or any other of the features usually associated with unconformities, either in the Amingure-Dakacha area or along the well exposed junction at Hegalu. The most significant evidence that the junction is conformable, however, is provided by the distinctive faunal assemblage collected immediately below it at nearly all exposures over a stretch of 30 miles.

The sequence in the lower part of the Mandera Series was determined in the Amingure, Dabeit and Lugh Gudediye areas:—

	<i>Thickness (feet)</i>
<i>Gudediye Beds</i>	
12. <i>Gudediye Limestone</i> ; dolomitic and sandy	2
11. Sandstones and shales	c.50
10. Massive sandstones	10
9. Siltstones and shales	70
8. Sandstone	10
7. Shales and thin sandstones	30
<i>Amingure Beds</i>	
6. <i>Amingure Limestone</i> ; Brown dolomite with clay galls and fish teeth (?) increasingly sandy to the west and grading into a calcareous sandstone	2
5. Siltstone and shale with a 2 ft. red impure dolomite band, weathering yellow and with small gastropods and ostracods	8
4. Limestone, brown and silty	2
3. Sandstone	6
2. Sandy marls and siltstones	10
1. Green shales, becoming gypsiferous to the east	10
	210

The thickness in the Matasafara area, tentatively deduced from isolated outcrops, is thought to be in the region of 300 to 350 feet.

The succession measured in the Hegalu hills in Somalia is as follows:—

	<i>Thickness (feet)</i>
(Marehan Sandstones)	
	<i>unconformity</i>
6. Brown silty limestone; correlated with the Amingure limestone	2
5. Purple and green shales with calcareous reddish mudstone with ostracods at the top, correlated with bed 5 of the Amingure section	20
4. Sandstone with thin calcareous intercalations	20
3. Calcareous brown and red mudstones with shales	10
2. Brown, yellow-weathering, limestone	1
1. Green shales (lower part not exposed)	160 (?)
	<hr/>
(Daua Limestone Series)	213
	<hr/>

If the correlation adopted is correct, it is evident that there is a great thickening of the beds between Amingure and Hegalu.

All the non-calcareous beds of the lower part of the succession thicken rapidly to the east away from the junction, where they are exposed in the Gudediye valley and the adjacent hills. The lowermost green shales become gypsiferous to the east with a rapid increase in thickness in that direction, while the overlying siltstones, often showing slump structures immediately above the shales, become more important. The red dolomitic band intercalated in bed 5 was used jointly with the Amingure Limestone as a most distinctive and consistent horizon marker in the Dabeit and Gudediye areas. The same beds were also used to correlate the lower part of the Mandra Series in the northern extension of the Hegalu hills with the succession exposed in the west.

East of the Gudediye valley exposures of beds 7 to 9 occur as low isolated hillocks, planed off during Pleistocene times. At one of the siltstone outcrops curved calcareous sandstone lenticles like boomerangs lie scattered on the surface with green gypsum crystals of Pleistocene age. The lenticles are also found *in situ*, when it is seen that they are infillings of ripple-marks in the siltstones.

The sandstones of bed 10 shows extreme lateral variation in thickness; towards the east the thickest portion seen forms tors and crags up to 50 feet high. The succeeding beds, consisting mainly of red shales, siltstones, sandstones and some calcareous deposits are exposed along the base of the low escarpment to the east of the Gudediye river. They are themselves overlain by bright, usually purplish, shales becoming buff towards the top where they are overlain by the Gudediye Limestone. Some poorly preserved internal casts of a lamellibranch were collected some 35 feet below the Gudediye Limestone. Thin pockets of gypsum also occur in these beds. The Gudediye Limestone from another section is described on a later page (p. 35).

The wide variety of rock types composing the lowermost part of the series is notable, and the sediments usually grade rapidly from one kind to another. The transition from the Dakacha Limestones to the Mandra Series is recognised under the microscope by the inclusion of well-sorted clastic grains of quartz and felspar in the limestone, which grades into the sandstones forming the base of the Mandra Series in the Amingure area.

The fossiliferous dolomite (specimen 16/114) in bed 5 contains rounded fragments of silty fine-grained limestone and calcareous siltstones and sandstones. It also contains isotropic grains up to 2 mm. across, some of which appear to have organic structure, and may be fragments of bone. This bed can be identified in the succession at Hegalu, but the limestone occurring above it, although in the same stratigraphical position, does not exhibit the lithological peculiarities that make it so distinctive in the Dabeit-Gudediye area. Here it is a fine-grained dark brown recrystallized rock containing fish teeth (?) and numerous small yellow clay galls which weather out and impart to it a rough pitted surface. The clay galls average about 0.5 mm. in diameter and are rimmed by ferruginous material and cemented by dolomitic carbonate. Limonite appears interstitially and as small irregular

veins and patches, and a little glauconite is present. At Dabeit the same horizon is represented by a calcareous sandstone (16/117, 16/118) containing 80 per cent of sub-rounded clastic grains consisting of quartz, plagioclase and potash felspar with a few grains of tourmaline in a matrix of dolomite, calcite and limonite. Glauconite grains are present in both specimens collected, but are more prominent in 16/117. A section of a fish tooth displays radiating fibres of a phosphatic mineral (?). Further away from the edge of the depositional basin clastic grains are nearly absent, their place being taken by the fine-grained clay galls of the Hegalu rock.

Glauconite is present in nearly all the sediments of the Mander Series, but is most abundant in the lower part of the succession where it is frequently encountered as accumulations in the troughs between ripple-marks or as infilling of borings. Its presence along bedding planes increases the fissility of the rocks.

The siltstones of this part of the series are often calcareous, their clastic grains being cemented by a carbonate that is usually dolomitic. There is every gradation from coarse siltstones to fine-grained sandstones, but the average size of the clastic grains in the siltstones is between 0.06 and 0.08 mm. across. The detrital grains are mainly quartz and felspar, the latter mineral being usually slightly altered, with minor quantities of tourmaline and zircon and accessory muscovite, sphene, apatite and monazite. A banded appearance is sometimes imparted by segregations of glauconite. The grading of the clastic grains is nearly always poor.

The Gudediye and Gingo Beds are the best exposed of all the sediments of the Mander Series, and can be measured where they overlie the Amingure beds in the hills at Maiaasafara and Bila Machesa:—

	<i>Thickness (feet)</i>
<i>Gingo Beds</i>	
17. Thinly bedded greyish brown dolomite	2
16. Reddish brown flaggy calcareous siltstone	1
15. Brown thinly bedded dolomite	2
14. Sandy marls	12
13. Calcareous sandstone	3
12. Fine-grained marly sandstones	32
<i>Gudediye Beds</i>	
11. Brown sandy limestone— <i>Gudediye Limestone</i>	6
10. Sandy shales and marls with thin sandstones and pockets of gypsum	45
9. Silty sandstones	8
8. Silty shales	12
7. Silty sandstones	12
6. Sandy shales with thin limestones	45
5. Flaggy sandstones	11
4. Shales with thin sandstones and limestones	15
3. Brown silty limestone	1
2. Shales with thin silty limestones	10
1. Fossiliferous calcareous sandstones (Amingure Limestone)	c.22

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The bottom fossiliferous deposit of the Gudediye Beds is very consistent along the base of the Gingo hills to the south-west, and contains the following fossils which unfortunately, as Dr. Cox points out, give no evidence of the age of the rocks as the most distinctive form is a new species:—

Tancredia ? sp., internal moulds,
 "Eocallista" merlai Venzo, internal moulds,
Corbula sp., internal moulds,
Myopholas sp. nov., external moulds and "steinkern" of a very characteristic pholadiform with radial ribbing.

The Gudediye Limestone (16/109) is a finely crystalline brown sandy limestone with dark brown irregular lenticles and small elongated cavities parallel to the bedding. The weathered surface shows the fine laminations characteristic of sandy limestones. Under the microscope the laminations are seen as concentrations of sub-angular grains of quartz and felspar with occasional tourmaline and zircon, cemented by a dusty calcite matrix, the grains varying in size from 0.03 to 0.10 mm. in diameter. The clastic grains form approximately 30 per cent of the total volume of the rock but sometimes nearly 50 per cent of the sandy laminations themselves. Limonite occurs interstitially as cavity linings or introduced with manganese oxide along the bedding planes. Yellowish opaline quartz occurs as rounded grains and spherules, usually with numerous small limonitic inclusions.

The sandstones in the lower part of the Gingo beds are often calcareous. Specimen 16/110, an example collected at Matasafara, is buff coloured and has partly sugary texture due to the presence of nodular crystalline portions that impart a brown pitted surface to the outcrops. The rock consists of some 60 per cent irregular, sub-angular to sub-rounded, and sometimes rounded, clastic grains, approximately 40 per cent being quartz and 20 per cent felspar. The felspar consists of large rounded grains of orthoclase and small, usually sub-angular, microcline and plagioclase. The potash felspar is partly replaced by calcite along the cleavages. The clastic grains are poorly sorted, varying in size from about 0.03 to 1 mm. across. The matrix consists of recrystallized calcite or aggregates of small detrital calcite grains, very often with much limonite.

The Gingo Dolomite (specimen 16/108), a light greyish brown rock, is a coarsely crystalline mosaic of dolomite rhombohedrons with numerous small inclusions. A few small clastic quartz grains are present, while limonite borders the dolomite crystals or occurs interstitially.

The succeeding Jirma Beds are exposed at Jirma hill, eight miles west of Mandera, and in the hills to the south of Jirma:—

<i>Jirma Beds</i>	<i>Thickness (feet)</i>
8. <i>Jirma Limestone</i> . Greyish brown impure dolomitic limestone	4
7. Shaly marls with rare casts of lamellibranchs	15
6. Reddish marls with fragments of fossil wood	4
5. Sandy shales	4
4. Fairly massive sandstone	8
3. Shales (poorly exposed)	8
2. Massive sandstone	10
1. Sandy shales (Gingo Dolomite)	20
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A 17-foot section of the upper part of the beds is also seen at Shefshef, five miles west of Mandera:—

	<i>Thickness (feet)</i>
6. <i>Jirma Limestone</i> ; brown ripple-marked limestone	4
5. Marly conglomerate with shale pebbles	1
4. Pale green marly shales	4
3. Flaggy cross-bedded sandstone	1
2. Pale green marly shales	4
1. Silty cross-bedded sandstone	3

The two sandstone bands form prominent features when they increase in thickness to the south-west, and can be readily followed along the escarpment as they weather out as stacks (Plate IIb). The sandstones are soft and friable, cross-bedded, and red-brown in colour. The angular to sub-angular clastic grains in them (specimen 16/107) range from 0.1 to 0.2 mm. across and on the whole are well-graded at about 0.15 mm. They consist mainly of quartz but microcline, zircon, tourmaline and plagioclase are also present. Small rounded grains of glauconite occur sparsely, while the interstices are occupied by fine-grained limonite with some hematite.

The Jirma Limestone is greyish brown and finely crystalline, with small cracks and solution cavities lined by ferruginous material. The microscope discloses a coarse mosaic of calcite and dolomite containing a few patchily distributed clastic quartz grains (specimen 16/106). Fine limonitic material is present, particularly in patches of the rock that contain indistinct oolites that have been almost destroyed by recrystallization.

The sequence of the next higher beds in the Mandera Series—the Bur Gawse Beds—was measured three miles west of Koromi:—

<i>Bur Gawse Beds</i>	<i>Thickness (feet)</i>
7. <i>Bur Gawse Limestone</i> . Ripple-marked, cross-bedded sandy limestone	6
6. Flaggy sandy shales grading into pure green shales with an increase in thickness to the south-east	30
5. Cross-bedded sandstone	10
4. Sandy shales	30
3. Prominent cross-bedded sandstone	4
2. Sandy shales	25
1. Sandy marls with fossil wood fragments and (?) fish remains (Jirma Limestone)	2
	107

The upper part of the Bur Gawse Beds is also well-exposed along the low escarpment 10 to 12 miles south-west of Mandera.

The sandstone of bed No. 5 of the measured section is soft, friable, and weathers to a red-brown colour; it becomes prominent in the Hagersu area where it is much thicker. Microscopically it resembles the sandstones of the Marehan Series, but the presence of glauconite that can be detected under the microscope contradicts any suggestion that the rock might have a terrestrial origin. The rock (16/105) is composed of sub-rounded to sub-angular closely packed grains of quartz, detrital hematite, fragments of prisms of tourmaline, some microcline and plagioclase, and occasional zircon and monazite. The size of the grains varies from 0.1 to 0.2 mm. and the banding of the rock is produced by dark streaks containing aggregates of fine grains of hematite and limonite.

The Bur Gawse Limestone is distinctive in being sandy and in displaying cross-bedding on the weathered surfaces. The hand-specimen (16/103) is brown to dark brown and finely laminated. The microscope discloses the presence of nearly 50 per cent of clastic grains, quartz and feldspar being the major constituents while a little tourmaline, zircon and some muscovite comprise the remainder. The matrix is composed of fine-grained calcite enclosing many dust-like limonitic granules. The laminations are due to variations in the size and abundance of the clastic grains.

The overlying Finaguba Beds are exposed in the low escarpment south of Mandera along the international boundary, the greatest thickness being found at Banioli hill, which is partly in Somalia. The section exposed at Finaguba is as follows:—

	<i>Thickness (feet)</i>
<i>Finaguba Beds</i>	
14. <i>Finaguba Limestone</i> . Yellowish brown dolomitic limestone	5
13. Gypsiferous marls and shales	6
12. Silty shales with two thin red-brown flaggy siltstone bands	20
11. Buff sandy flagstones	1
10. Red silty flagstones	½
9. Shales	5
8. Flaggy ripple-marked sandstone	1
7. Shales	2
6. Friable micaceous sandstone	2
5. Vari-coloured shales	45
4. Soft yellow fossiliferous marly shale	1½
3. Laminated marly shale	1
2. Grey marly shale	15
1. Reddish marly shale (base not exposed)	6
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Further to the south these beds are underlain by 50 feet of vari-coloured gypsiferous shales. Lateral variation is evident, for example in the appearance of a thick ferruginous sandstone in the succession between Finaguba and Banioli, which is represented at Finaguba by a thin band of flaggy micaceous sandstone. Great lateral variation of other sandy beds can be seen over short distances.

The sandstones of the upper part of the Mandera Series are usually laminated, buff-coloured and sugary, but often grade into massive ferruginous sandstones. They are fissile along the bedding owing to alternating fine- and coarser-grained layers, or to glauconitic bands. They are composed mainly of closely packed angular to sub-rounded grains of quartz and slightly altered microcline with a few flakes of muscovite and some zircon (specimen 16/98). Black patches of some organic material are often encountered, while glauconite is sometimes an important constituent.

The thin red flaggy horizons are conspicuous and often form benches along the escarpments. Under the microscope they are seen to be calcareous siltstones, the red colouration being due to the presence of a large percentage of hematite and limonite. The marly shales contain sparse small detrital grains of quartz and feldspar in a slightly calcareous clayey matrix.

The Finaguba Limestone (Specimen 16/131, from four miles south of Mandera) is dolomitic and contains clusters of magnetite grains that give rise to numerous small black spots in the hand-specimen.

The measured sections of the Mandera Series indicate a total thickness of approximately 770 feet, but it is believed that there is a thickness in the region of 2,000 feet in the eastern part of the area, as indicated by Ayers (1952, p. 15). The discrepancy in the figures is ascribed to the great increase in thickness of the argillaceous and arenaceous sediments towards the centre of the depositional basin and to the fact that the sections exposed consist of sediments that were deposited along the fringes of the regressing sea.

The following fossils have been listed by Venzo (1948, p. 166-7) as yielded by the Finaguba (Cud Finagubi) Beds:—

- Ampullina* cf. *coxi* Stefanini,
- Neritopsis* cf. *bajociensis* d'Orb.,
- Exogyra nana* (Sow.),
- E. vinassai* Diaz-Romero,
- E. jubaensis* Venzo,
- Exogyra* sp. nov. aff. *praevirgula* Douvillé and Jourdy,
- Exogyra* (?) *agipi* Venzo,
- Modiolus imbricatus* Sow.,
- Modiolus* (*Inoperna*) *plicatus* Sow.,
- Lycettia dalpiazii* Venzo,

Pteroperna cf. *plana* Lycett.,
Nucula (*Palaeonucula*) sp. nov. aff. *nodifera* Terq. and Jourd.,
Grammatodon (*Indogrammatodon*) *virgatus* (Sow.),
G. (*Indogrammatodon*) *virgatus* (Sow.) var. *lasti* (Müller),
G. (*Indogrammatodon*) *virgatus* (Sow.) var. *trigona* Venzo.
G. (*Indogrammatodon*) *agipi* Venzo.
G. (*Indogrammatodon*) sp. nov.,
Eonavicula minuta (J. de C. Sow.),
E. minuta (J. de C. Sow.) var. *distorta* Venzo.
E. glabra Venzo,
Barbatia cf. *vicinalis* Bouillierie,
Trigonia (*Lyriodon*) *brevicostata* Kitchin,
T. (*Lyriodon*) *dainellii* Venzo,
T. (*Lyriodon*) *dainellii* var. *elongata* Venzo,
T. (*Lyriodon*) *dainellii* var. *subpullus* Venzo,
T. (*Lyriodon*) *dainellii* var. *crassecostata* Venzo,
T. (*Lyriodon*) *dainellii* var. *subtilecostata* Venzo,
T. (*Lyriodon*) *dainellii* var. *orbicularis* Venzo,
T. (*Lyriodon*) *cecionii* Venzo,
T. (*Lyriodon*) *migliorinii* Venzo,
T. (*Lyriodon*) *migliorinii* var. *spissecostata* Venzo,
T. (*Lyriodon*) *migliorinii* var. *obliqua* Venzo,
T. (*Lyriodon*) *agipi* Venzo,
T. (*Lyriodon*) *agipi* var. *transversa* Venzo.
Trigonia (*Laevitrigonia*) *stefaninii* Venzo,
T. (*Laevitrigonia*) *stefaninii* var. *rarecostata* Venzo.
T. (*Laevitrigonia*) *stefaninii* var. *spissecostata* Venzo,
T. (*Laevitrigonia*) *stefaninii* var. *anteumbonata* Venzo,
T. (*Laevitrigonia*) *stefaninii* var. *medioumbonata* Venzo,
T. (*Laevitrigonia*) *stefaninii* var. *transversa* Venzo,
T. (*Laevitrigonia*) *stefaninii* var. *curta* Venzo,
T. (*Laevitrigonia*) *stefaninii* var. *obliqua* Venzo,
Anisocardia loweana (Morris and Lycett.) var. *alcyon* (d'Orb.),
A. loweana (Morris and Lycett.) var. *ovalis* Venzo,
Pseudisocardia migliorinii Venzo,
Isocyprina cecionii (Venzo),
Eocallista merlai Venzo,
Eocallista sp.,
Corbis cf. *lajoyei* d'Archiac,
Sphaeriola cf. *madridi* (d'Archiac),
Sphaeriola nistai (Venzo),
Sphaera madagascariensis Newton,
S. madagascariensis Newton var. *minor*,
S. madagascariensis Newton var. *crasse-rugulosa* Venzo.
S. madagascariensis Newton var. *elongata* Venzo,
Quenstedtia cf. *angusta* Terq. and Jourd.,
Q. trigonula Terq. and Jourd.,
Q. jubaensis Venzo,
Q. gortanii Venzo,
Gresslya peregrina (Phill.),
G. truncata Agass.,
Ceratomya jubaensis Venzo,
Mactromya agipi Venzo,
Myopholas aff. *acuticostata* Sow.

Heligmus is also mentioned as occurring sparsely within the Finaguba Limestone (Venzo, 1948, p. 117). As a result of his identifications Venzo dated the Finaguba Beds as Bathonian and took the Finaguba Limestone to represent the base of the Callovian. It was stated in Ayers' report (1952, p. 27) however, that Dr. L. R. Cox considers "the dating somewhat questionable, as the species are individually long-ranged, or (in some cases) identifications are doubtful". Further in a letter to the Mines and Geological Department, Nairobi, Dr. Cox wrote regarding Venzo's publication "I have carefully studied the fossil descriptions and figures and can find no definite confirmation of a Bathonian age; in fact, the small *Trigonias* which seem to occur there in great abundance are rather suggestive of Upper Jurassic types".

There is no doubt whatever that the Mandera Series overlies the Daua Limestone Series, in the upper beds of which fossils occur that definitely indicate upper Jurassic age. It is believed that the Mandera Series is uppermost Jurassic, i.e. Tithonian, and perhaps even extends into the lower Cretaceous.

Support for the uppermost Jurassic age of the Mandera Series is found in the Jurassic stratigraphy of areas further north. The Kimmeridgian-Portlandian Gabredarre Formation of Ethiopia, for example, is overlain by several hundred feet of gypsum with impure shale and marl, the exact age of which is unknown, however, because of lack of fossils (Taylor, 1948A, p. 253). The Gawan limestones of north-central Somaliland Protectorate (Somaliland Oil Exploration Company Ltd., 1954, p. 7, where the limestones are dated as Portlandian) become sandy towards the top and in other parts of the country isolated basins of deposition include evaporites, again indicating regression at this stage of the Jurassic.

If any contemporaneous deposits exist along the Kenya coast, they are not exposed (Caswell, 1953, p. 18) and the controversy regarding the Tendaguru Beds render correlation with beds in Tanganyika undesirable. It is significant, however, that, in Madagascar, where the uppermost Jurassic is separated into two stages, Portlandian and Tithonian, the Portlandian is represented by sandy and glauconitic beds and the Tithonian by mainly calcareous and sandy beds that are sometimes oolitic and glauconitic (Besairie, 1946, p. 18).

It is clear that the Mandera Series represents the regressional phase of the Jurassic sea that occurred along the eastern flank of Africa and in the Middle East towards the close of the Jurassic period. There are no grounds for correlation with the Lugh Group of Somalia, and it is suggested that perhaps a faulted structure like that at Hegalu has allowed the exposure of Lower Jurassic beds—the true Lugh beds—at Lugh Ferrandi in Somalia, and that lithological similarity caused the confusion between them and the eastern extension into Somalia of the Mandera Series. During the present survey an attempt was made to unravel the existing discord but the authorities in Somalia would not allow examination of the Lugh beds.

2. Cretaceous System—The Marehan Series

The Marehan Series occupies the major portion of the area and it is best exposed in the Raiya, Bamba, Willeh, Garri and Danissa hills. Where the hills give place to the end-Tertiary peneplain in the south-east scattered outcrops form low knolls or rim the edges of numerous pans. The determination of the exact stratigraphical position of these isolated outcrops was difficult, and lithological characteristics usually had to be taken as the deciding factor.

The name "Marehan Sandstone" was first adopted by Weir (1929, p. 13) who distinguished the sandstones that cap the hills in north-east Kenya from the Lugh Group of Somalia, considering them to be of uppermost Jurassic or lower Cretaceous age. Dixey (1948, p. 40) described what he thought was a transition between the Daua Limestone Series and the Marehan Series and suggested an upper Jurassic age for the latter. Ayers (1952, p. 15) considered that the Mandera Series was a lateral facies variation of the lower part of the Marehan Series and, as a result, believed that the Mandera Series was separated from the Daua Limestone Series by the same unconformity as he had recognized at the base of the Marehan Series. During the present survey the transgression of the base of the Marehan Series, across both the Mandera Series and the Daua Limestone Series, as well as the angularity existing between the Jurassic rocks and the Marehan Series, were clearly established.

The Marehan Series was given its name and divided into two parts by Saggerson and Miller (1957, p. 23) viz:—

Marehan Series	{	2. Marehan Sandstones
		1. Danissa Beds

The Danissa Beds consist mainly of siltstones, sandstones and limestones representing estuarine deposition, and are succeeded by the terrestrially deposited Marehan Sandstones. As is expected with estuarine deposits the Danissa Beds vary constantly along the strike, but at least three distinct horizons can be traced over most of the area.

Fossils collected from the Danissa beds during the present survey and those yielded by equivalent beds in the adjoining Takabba-Wergudud area to the south-west indicate a lower Cretaceous (Wealdan) age. Also by comparison with similar deposits in Ethiopia and Somaliland Protectorate, it seems that the deposition of the Marehan Series must be restricted to the interval between the Neocomian and Turonian stages of the Cretaceous period.

The succession of the Marehan Series in the eastern extension of the Raiya hills in the vicinity of Sarego can be used as a basis in describing the succession:—

	<i>Thickness</i> (feet)
<i>Marehan Sandstones</i>	
9. Marehan Sandstones	100
<i>Danissa Beds</i>	
8. Silty sandstones	60
7. Prominent massive cross-bedded sandstones	20
6. Silty sandstones and marls	40
5. Massive sandstone, forming stacks on hillsides	20
4. Thin ferruginous sandy clay	—
3. Marls, silty sandstones and shales with one fairly prominent sandstone band	150
2. Hard red-brown calcareous siltstone	2
1. Marls with two fairly prominent sandstone bands; mainly sandy at the base	50
	442

Bed 1 becomes shaly in the northern end of the Raiya hills at Figfirya, where it is soft and green, sometimes gypsiferous, and where there is a thin basal band of brown impure limestone. Bed 2 is a prominent horizon in the northern Raiya hills where it is non-fossiliferous, though it contains trigonias 11 miles to the south at Odda and is correlated with a red calcareous siltstone containing a profusion of casts, identified by Dr. Cox as *Trigonia* sp. nov., probably *T. brevicostata* Venzo (*non* Kitchin), that occurs at Bur Hafura. This horizon proved to be a most useful marker in widely separated areas. Under the microscope it is seen to consist of angular clastic grains, 0.03 to 0.06 mm. in diameter, of which quartz makes up 35 per cent of the rock and felspar (orthoclase and occasional microcline) 15 per cent, cemented by a densely ferruginous matrix of fine-grained calcite. Occasional grains of tourmaline are present.

At Figfirya bed 3 includes a thin sugary-textured sandstone which contains numerous leaf impressions identified by Dr. Franks as *Zamites* sp. of lower Cretaceous age, and is overlain by silty shales with yellow bands containing poorly preserved casts of lamellibranchs. A red mudstone with numerous small gastropods and lamellibranchs (*Corbula* ? sp.) is included in the beds numbered 6. Bed 7 increases in thickness to 50 feet to the north-west and forms prominent stacks from which Figfirya derives its name. The sandstones of bed 5 are illustrated in Plate III a.

The thin ferruginous band, No. 4 in the Sarego succession, was also used as a marker in the Raiya and Hegalu areas. It occurs approximately 200 feet above the base of the Danissa Beds and also in the succession along the western slopes of the Raiya hills, which is as follows:—

	<i>Thickness</i> (feet)
<i>Marehan Sandstones</i>	
21. Marehan Sandstones—Massive cross-bedded whitish pink, red-weathering sandstones with three thin interbedded siltstone bands, the most prominent being 70 feet from the base	100
<i>Danissa Beds</i>	
20. Variegated siltstones, mainly red and purple	7
19. Massive cross-bedded sandstone with small white clayey specks in part	5
18. Variegated siltstones with fossilized twigs	12
17. Massive cross-bedded whitish sandstone	8
16. Variegated shales and siltstones	10
15. Prominent, fairly massive whitish sandstone	6
14. Variegated silty shales and siltstones with clay galls	20
13. Whitish silty sandstone	4
12. Thin brown calcareous silicified sandstone, with poorly preserved lamellibranch casts	—

11. Finely laminated variegated silty shales, sandy in lower parts	30
10. Finely laminated current-bedded silty sandstone ..	5
9. Thin greyish brown and purplish sandy shales, often micaceous and current-bedded	65
8. Thin ferruginous silty clay (c.f. No. 4 in the Sarego section p. 40)	—
7. Yellowish white sandstones, upper layers becoming brown with numerous small dark brown spots ..	15
6. Silty yellow and red shales	30
5. Yellowish white sandstone	15
4. Yellow and green silty shales, shales and siltstones ..	25
3. Silty sandstones grading into siltstones and shales downwards	80
2. Impure grey-brown limestone (cf. No. 2 in the Sarego section, p. 40)	1
1. Mainly shales with thin sandstones. Sandstone at the base	40
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The colours of the variegated siltstones and silty shales are most significant in changing from pale green to yellow in the lower parts to bright yellow and red and eventually to bright red and purple in the upper parts of the succession. The lower layers of the sandstones often contain clay galls derived from underlying variegated siltstones. The succession undoubtedly indicates repeated fluctuations of sea-level but with gradual desiccation of the area during the deposition of the representatives of the Cretaceous System.

The ferruginous silty clay (bed 8 in the tabulation above), which is a distinct feature of the Danissa Beds in the Raiya hills was also found to be most persistent in the Burki Dima Dar hills, south of Hafura, where it assists in the determination that the beds there have a thickness of only 200 to 300 feet.

A thin section of the silicified sandstone of bed 12 (16/168) reveals a medium-grained mosaic of interlocking grains of quartz and some felspar, enclosing several tapering phosphatic fossil remains up to more than 2 mm. in length. The rock also contains small phosphatic nodules and clastic tourmaline and zircon. A little calcite is seen in association with the phosphatic bodies, but the reaction on the bedding of the rock when it is tested with dilute hydrochloric acid indicates that carbonate is more abundant than appears in the thin section. Limonite occurs with the fossil remains or as accumulations of small grains, sometimes in association with a little hematite.

The dark brown spots of the upper part of the sandstone of bed 7 (16/169) are caused by interstitial concentrations of limonite with small nodules of hematite. There is also some argillaceous matter within the mosaic of well-sorted, medium-grained, sub-rounded grains of quartz that forms the bulk of the rock. Some felspar and a little muscovite are also present.

A brick-red sandstone (16/170) collected from the base of the Marehan Sandstones contains purple and white silty clay lenticles derived by contemporary erosion from the siltstones immediately underlying it. Under the microscope the rock is seen to consist mainly of angular to rounded quartz grains, which are fairly well-sorted with average diameter about 0.2 mm., the interstitial space being occupied by granular limonite with a little hematite. Some magnetite also occurs interstitially, while well-rounded grains of tourmaline, zircon and flakes of muscovite are infrequent. The included fragments of silt consist of small angular quartz grains in a dense argillaceous matrix which usually is highly manganiferous. One such inclusion in the thin section has a heavily oxidized skin, while its interior is free from iron oxides, suggesting that the fragment suffered sub-aerial exposure before being washed into its present host. Another fragment is a crimson-stained mudstone that contains clear patches that resemble kaolinite aggregates.

The succession of the Marehan Series further south-west on the Bamba and Garri hills is essentially similar to that described above but with some slight variations. In the northern Bamba hills a greyish brown gritty limestone, one foot thick, occurs at the base of the Danissa Beds. It weathers with a rough surface owing to the presence of clastic grains, while the

fresh surfaces display abundant soft whitish to yellow nodules and some fossil fragments. In thin section (16/218) the mineral clastic grains are seen to range in size from 0.01 to 1.5 mm. across and to consist of quartz with undulose extinction, plagioclase, orthoclase and microcline, the potash feldspars being corroded by the crystalline calcite matrix. Spherical and rod-like bodies of variable size, the rod-like bodies being up to 5 mm. in length, are numerous throughout and are composed of fine-grained calcite rimmed by dense carbonate. Some of these may represent recrystallized shell fragments, but many appear to be derived fragments of limestone. There are also pellets of siltstones, occasional well-rounded grains of chert, small phosphate pebbles, and one grain composed of a fine-grained mosaic of quartz containing numerous small hornblende prisms. Limonite is mostly confined to irregular interstitial patches. The rock contains fragments of shell and a few poorly preserved foraminifera, which may have been derived from the underlying Jurassic sediments. Further to the south this bed contains numerous well-rounded yellow calcareous pebbles and was mapped by Ayers (1952, Map No. 5). It is a limestone conglomerate and forms a distinct base to the Danissa beds. Microscopically this rock (16/225) is generally similar to that described above, but the pebbles are composed of fine-grained calcite bordered by extremely fine-grained limonite-rich rims. Coarse calcite forms part of the matrix and is frequently partly replaced by a lattice of limonite which has accumulated preferentially along the cleavages.

A very distinctive limestone, buff to light brown, with small cavities, overlies the basal bed in the Bamba area. Owing to poor exposures a good section could not be measured but the limestone is approximately 5 feet thick in the southern Bamba hills, where specimen 16/215 was collected. Under the microscope the rock is seen to consist mainly of dolomite with some interstitial limonite and calcite and with 10 to 15 per cent of small sub-angular quartz grains in certain bands.

Bed 2 of the Raiya succession (p. 41) is again evident in the Bamba hills as a thin brown impure limestone approximately 50 feet above the base of the Danissa Beds, the rocks below and above being mainly poorly exposed silts and silty sandstones.

Along the western flank of the Raiya hills and in the Bamba and Garri hills two sandy zones in the Danissa Beds stand out prominently on the hill slopes and are represented by lines on the map. The lower bench is formed mainly by Bed 10 of the Raiya succession, but includes the upper part of Bed 9 and the lower sandy ten feet of Bed 11. The upper zone includes beds 15 to 19. These prominent sandy horizons are represented by beds 5 and 7 in the Sarego sequence. A distinctive fossiliferous impure limestone occurs between the two sandstone bands in the Bamba hills, where it is approximately 3 feet thick and contains brachiopods and cidarid spines. The thickness of this bed increases to about 5 feet in the Garri hills where it overlies a silty bed that contains fossilized plant remains, notably *Weichselia reticulata* (Saggerson and Miller, 1957, p. 27). The impure limestone can be correlated with bed 12 of the stratigraphical sequence of the western Raiya slopes and with the red fossiliferous mudstone of Figfiry mentioned on page 40. In thin section this limestone is seen to consist of a fine-grained mosaic of crystalline calcite with a few small sub-angular grains of quartz. The carbonate is dusty with numerous minute ferruginous inclusions especially where they enclose small irregular patches of magnetite (?). Veins of clear coarsely crystalline calcite occur bordered by limonite.

The marker horizons of the Danissa Beds, tabulated in order of importance are, therefore, as follows—

1. A one- to two-foot thick sandy limestone or calcareous siltstone, which is dark red and fossiliferous in parts in the north and east, becoming thinner and greyish brown towards the south-west where it is non-fossiliferous, occurs 40 to 50 feet above the base.
2. A thin ferruginous sandy clay occurs approximately 200 feet above the base in the north and east, but has not been found in the Bamba, Garri or Danissa hills, perhaps due to poor exposure.
3. A prominent sandstone or sandy zone occurs 200 feet above the base in the north and 250 feet above the base in the south-west.
4. A three- to five-foot thick fossiliferous impure limestone in the south-west, which thins towards the north with decrease in carbonate, occurs between marker bed 3 and marker bed 5. In the Garri hills it overlies a silty horizon with numerous plant remains.

5. A prominent sandstone horizon which is 330 feet above the base in the Garri hills and 260 feet above the base in the northern extension of the Danissa Beds.

It is clear that a thickening of the Danissa Beds as well as of the Marehan sandstones takes place progressively towards the south, which may indicate that the deepest part of the basin of deposition existed south or south-east of the area.

The transgression of the Cretaceous rocks of the area across the beds of the Jurassic System is clearly revealed by the mapping. When the junction between the Jurassic and Cretaceous sediments is followed on the map, it can be seen that the Marehan Series, which overlies the Mandera Series in the north-east, overlaps onto the Dakacha Limestones along the base of the Raiya hills and eventually on to the Seir Limestones along the foot of the Bamba hills.

Along the western slope of the Hegalu hills, two miles north of Finno, the unconformable junction is perfectly displayed in the 4° angle between the base of the Marehan Series and the bedding of the Mandera Series (Plate IV *a*). Underlying the Marehan Series on the northern slope of Finno there is a thick ferricrete which may represent the period of exposure and non-deposition that existed during uppermost Jurassic times and some period during the lower Cretaceous. The uppermost beds of the Mandera Series here contain numerous worm-borings and a thin section shows that only slight silicification of the sandstone (16/126) has taken place, though the fillings of the worm-borings are hard and quartzitic.

At Sarego, the base of the Marehan Series consists of undisturbed laminated sandy siltstones, resting unconformably on fine-grained sandstones of the Mandera Series which are mildly puckered, the folds plunging at a small angle in an easterly direction (Plate III *a*). At the junction a thin ferruginous layer covers the sandstones of the Mandera Series and a soft pale yellowish green clay occasionally fills small synclines. The gritty or pebbly limestone at the base of the Danissa Beds in the Bamba hills confirms the break in deposition, the clastic fragments being derived from the calcareous Jurassic System rocks as well as from the Basement System rocks further west.

Ripple-marks are common throughout the Danissa Beds, and indicate fast-flowing currents with the directions of flow varying considerably, but in the southern part of the area a prevalent flow to the N.N.E. is indicated. In the upper parts of the succession worm-borings are common, the rocks usually showing slight silicification.

Surface silicification of the sandstones has occurred to a small extent, for example as in specimen 16/200, a reddish brown, partly silicified, cross-bedded sandstone, in which the sub-angular to sub-rounded clastic grains are cemented by interstitial silica. Silicification along the fault striking N.N.E.-S.S.W. just west of Bur Hafura is unmistakable. Specimen 16/121 from the locality is a hard even-grained pink sandstone, in which the cement consists partly of secondary silica. A fault breccia (16/125) collected at Bur Mansa contains angular buff-coloured fragments rimmed by dark purplish borders, contained in a light purple streaky fine-grained matrix. A thin section reveals that this rock again is highly silicified.

The Marehan Sandstones cap the major hill ranges of Raiya, Bamba, Willeh, Garri and Danissa and of Hegalu in the east, giving rise to vertical cliff faces. Approximately 100 feet of the sandstones occur on top of the Raiya hills but a greater thickness is evident to the south, the Bamba and Willeh hills being capped by more than 200 feet while in the Danissa hills there is a thickness of nearly 400 feet. The increase of thickness exposed to the south-west is not due only to the fact that greater thicknesses were deposited to the south, but also results from post-depositional removal of the upper parts of the succession in the north.

The sandstones are massive and even-grained, pinkish to white in colour and weathering to a reddish brown hue. Bedding is hardly perceptible in small outcrops, and in larger exposures well-developed joints give rise to prominent stacks and vertical cliffs. Under the microscope a coarser texture, better sorting and a higher degree of rounding of grains distinguish the Marehan sandstones from sandstones of the Danissa Beds, although the mineralogical composition is the same.

The Marehan Series generally has a dip of 2° to 3° to the south-east, but in the southerly parts of the area horizontal beds and low westerly dips were recorded. The faulting in the neighbourhood of Bur Mansa and Hafura has resulted in higher than normal dips—steep dips, as much as 60° , were recorded along the Hegalu fault.

Silicified fossil wood fragments are often encountered in the Marehan Sandstones and Saggerson and Miller (1957, p. 27) also report the discovery of fish remains in them.

Suggestions on possible datings and correlation must be made with reserve at present until the fossils found in the Danissa Beds are identified and dated and, until more useful fossils are found in the Marehan Sandstones, little progress can be made with the detailed correlation and dating of the Marehan Series. In eastern Ethiopia the 700 foot thick Mustahil Limestones, which include some shale lenses, occur at the base of the Cretaceous System and comprise beds of Barremian, Aptian, Albian and Lower Cenomanian age according to Taylor (1948A, p. 253). These beds are overlain by 600 feet of unfossiliferous Ferfer gypsum, which is succeeded by 250 feet of limestones known as the Belet Uen Limestone, mainly of Cenomanian age though in their upper part the beds become more sandy and contain Turonian fossils. Fossils of Turonian age were first recorded from Ethiopia by Neuman (1902, p. 398) who worked on material from the Gillet mountains. The Belet Uen limestone grades upwards into the Jesomma Sandstone, which contains no fossils (Taylor, 1948 B). Lithologically there is hardly any ground for correlation of the Ethiopian succession with the lower Cretaceous of north-eastern Kenya where the sediments are mainly arenaceous, but the presence of two persistent limestone horizons containing marine fossils in the Danissa beds may be significant when compared with the Mustahil and Belet Uen Limestones. The description of the Jesomma Sandstone invites comparison with the Marehan Sandstones, but it is possible that the Danissa Beds may be the equivalent of the Mustahil Limestones alone, the succeeding Ferfer gypsum representing the Ethiopian products of the arid phase during which the Marehan Sandstones were laid down.

In Somaliland Protectorate considerable variations exist in the Cretaceous succession but palaeontological work has proved the existence of Barremian, Aptian, Albian and Senonian beds. (Somaliland Oil Exploration Co., Ltd., 1954, pp. 16-17.) In the north-east a fossiliferous limestone succession passes westwards into an arenaceous facies while unfossiliferous sandstones represent the Cretaceous in north-central Somaliland and along the edge of the Somaliland plateau.

Stefanini (1925, p. 1065) believed that the Mesozoic limestone series of Somalia probably extended without a break at least into the lower Cretaceous, on the grounds that fossils yielded by a limestone in the valley of the Webi Shebelli had previously been determined as Neocomian in age. Furon (1950, p. 294) however, in discussing the geology of Ethiopia and the Somalias, made it clear that a regression, when continental sandstones were deposited, marked the passage from Jurassic to Cretaceous periods and was followed by re-invasion by the sea during Barremian times. Stefanini noted that no upper Cretaceous rocks were known in Somalia (*op. cit.*, p. 1066).

The Freretown Limestones of coastal Kenya are Neocomian in age (e.g., see Caswell, 1953, pp. 24-25), but unfortunately the junction with the Jurassic sediments is not exposed. The Lower Cretaceous of Tanganyika is represented by a Neocomian marine horizon in the Tendaguru Beds and by a coral limestone of Aptian age in the Kiturika hills. At Makonde the unfossiliferous Maweni Sandstone Beds are overlain by the Newala Sandstones of terrestrial origin which are dated as Upper Cretaceous (Teale, 1936, p. 22, Wade, 1937, p. 40). Aitken (1956), as a result of later work, concludes that there is a considerable break in the sequence between the Jurassic and Cretaceous periods.

In Madagascar the Cretaceous is well-represented by marine sediments, but there is a break in the sedimentation representing the Santonian stage of the Upper Cretaceous (Besairie, 1930, pp. 91, *et. seq.*). Besairie (1956) shows that there is in Madagascar a complete passage from Jurassic to Cretaceous sediments.

Mountain-building had ceased by the end of the Jurassic in South Africa and subsequent subsidence resulted in the sea entering the structural troughs along the coastal margins in the south, as is indicated by estuarine deposits containing fossils of Neocomian age. Further north, on the east coast, the Cretaceous is represented by deposits of Neocomian to Albian age (Du Toit, 1954, p. 570). The Turonian stage is apparently not represented by marine deposits, but still higher (Senonian and Danien) beds are found in parts of South Africa (*op. cit.*, p. 372).

3. Cainozoic Sediments

Rocks of Cainozoic age in the Mander-Damassa area are mostly confined to the Daa valley and its vicinity, but representatives also occur as outliers or remnants further south and in a restricted basin at El Wak. The dating of the deposits depends mainly on

their altitude with relation to the river-bed of the Daua, and their relation to the erosion surfaces and river terraces, and was confirmed by the evidence of fossils only in one instance, by an artifact found *in situ*. The classification adopted in this report is as follows:—

Recent		Soil, alluvium and calcrete.
Pleistocene	Upper	Yellowish brown to grey soil, sandy in patches, often with calcrete nodules.
		El Wak Beds (gypsite and limestone) (?)
	Middle	Grits, soft silty limestones and conglomerates, calcrete, red-brown sandy soil
Pliocene	Lower	Shangalla limestones, pebbles and gypsum
	Upper	Borahra lacustrine deposits Laterite

(1) LATERITE

Small patches of laterite occur on the end-Tertiary peneplain north-east of El Wak and west of the Hegalu hills. Only one small outcrop of ferricrete was encountered, the usual occurrences being unconsolidated ferruginous gravels. The gravel has obviously been derived from the Marehan Series and cemented or coated by ferruginous material just below the surface. These deposits have been exposed and subject to erosion since early Pleistocene times.

(2) THE BORAHRA LACUSTRINE DEPOSITS

The Borahra deposits occur as three isolated outliers unconformably overlying the Jurassic limestones in the Borahra hills and north of the Bamba hills. The succession is thin in the south where it is composed of gritty gypsite with some milky chert, but increases to 60 feet in thickness in the northernmost outlier where it consists of 50 feet of gritty calcareous silt with pockets and large lenses of recrystallized gypsum and small lenses of a hard dark greyish green chert, the succession being capped by 10 feet of white, sometimes mottled, bedded chert. The chert is usually nearly translucent on fresh surfaces but becomes white on weathering, and often has a peculiar pitted surface. Milky bands contain fine dark lines parallel to the stratification which often displays small-scale slump structures. Numerous artifacts and chippings of the Stillbay Culture manufactured from the chert lie strewn on the surface at this locality. Under the microscope the colourless chert is seen to consist of radially fibrous chalcedony in a fine-grained chalcedonic matrix with opaline quartz, the fibrous chalcedony occurring in bands.

The Borahra sediments lie on the end-Tertiary peneplain and are taken to represent a Plio-Pleistocene age; they were probably deposited during part of the Kageran pluvial period.

The dip of the sediments cannot be measured directly, but from a distance a slight dip to the south-east is evident, which is consistent with the slope of the end-Tertiary peneplain. Rounded pebbles derived from the distinctive greyish green chert occur, often in profusion, on the succeeding Pleistocene erosion surfaces over large parts of the area to the north and north-east, and it is obvious that the Borahra sediments enjoyed a wider distribution during the early Pleistocene and were reduced to their present superficial extent during the succeeding pluvial phases.

The nature and constitution of the sediments seem to indicate a lacustrine environment of deposition, subject to droughts, when evaporites were formed, with the last stage represented by the deposition of colloidal silica. The presence of gypsum indicates the occurrence of shallow salt-water, while the cherts represent the colloidal silica that was brought in by rivers discharging into the lake and deposited when the fresh waters mingled with brackish water (Twenhofel, 1950, p. 409).

(3) PEBBLES AND CALCRETE OF THE MANDERA EROSION SURFACE

Pebbles and calcareous crustal deposits occur on the oldest Pleistocene erosion surface, which is structurally preserved by the resistant limestones of the Mandera area, the surface south-west of Mandera being strewn by silicified ferruginous sandstone pebbles and flint implements of the Somali Stillbay Culture.

To the east of Umbiso the Seir Limestones have a thin covering of sandstone presumed to be of similar age, the preservation of which is due to silicification of the uppermost layer. The sandstone (16/151) is medium-grained with thin bedding marked by alternating white and reddish layers. The microscope reveals fairly well-sorted, sub-rounded to angular quartz grains as the main constituent, accompanied by some altered felspar grains. Limonite

fills most of the interstitial spaces while small detrital grains of muscovite, tourmaline and hematite are accessory. Fine-grained yellowish calcareous clay occurs interstitially, with limonite forming occasional pellets.

These sediments occur on the oldest Pleistocene terrace and are considered to represent the later part of the lower Pleistocene.

(4) THE SHANGALLA LIMESTONES AND ASSOCIATED DEPOSITS

South and south-west of Rahmu the Jurassic sediments are unconformably capped by a hard white porcellaneous limestone, well-bedded in parts, which attains a thickness of nearly 50 feet four miles south of Rahmu, but thins towards the south-west against the slope of the surface on which deposition took place. The sequence is well-exposed in the valleys of the tributaries of the Daua river, notably the Lugh Shangalla.

The base of the Shangalla Limestones is conglomeratic in the north, grading upwards and to the south-west into calcareous grits. A conglomeratic limestone collected four miles west of Rahmu (16/136) consists of well-rounded pebbles up to 3 cms. in diameter and numerous shell fragments derived from the Jurassic sediments, cemented by a yellowish brown calcareous matrix. It is interesting to note that the majority of the pebbles are composed of the fine-grained buff porcellaneous Jurassic limestones that were not deposited after Lower Callovian times, indicating that the pebbles were derived from some distance to the west, probably from the Murri limestones where such porcellaneous limestones are often encountered. Occasional elongated pebbles lie with their longer axes parallel to the indistinct banding of the matrix of the conglomerate. Under the microscope the matrix is seen to consist of numerous shell fragments, angular clastic grains of quartz and felspar of variable size and some ooliths in a partly dolomitized calcite matrix. Pools of secondary quartz fill occasional cavities. Limonite is mainly restricted to the shell fragments and ooliths derived from the erosion of the Jurassic sediments, which probably also supplied the one rounded glauconite grain encountered in the thin section.

The conglomeratic limestone grades upwards into a gritty detrital limestone consisting of fossil fragments, limestone grains and small angular or larger rounded clastic quartz grains cemented by a coarsely crystalline calcite matrix. The detrital limestone granules vary in size from fine-grained to gravel size and sometimes contain small angular quartz grains, while the large quartz grains often consist of a sutured mosaic.

A calcarenite collected at Kordayu (16/181) is a buff-coloured limestone with rounded grey nodules of varying sizes and numerous small cavities. In thin section the rock is seen to consist of numerous fine-grained calcareous pellets, shell detritus and broken ooliths, all derived from the underlying Jurassic sediments, cemented by a mosaic of clear calcite. A few small angular clastic quartz and felspar grains occur scattered sparsely throughout the matrix.

The conglomeratic and gritty limestones are succeeded by bedded whitish buff limestones which make up the major part of the group. They form a hard capping and have a distinctive uneven weathered surface. They are composed of nodules and patches of slightly coarser calcareous material in a fine-grained homogeneous matrix. In thin section (16/135) finely divided calcite nodules, sometimes containing small angular quartz grains, separated by veins and pools of crystalline calcite, are seen. Large rounded or angular quartz grains are infrequently encountered, while some argillaceous material is occasionally seen within the fine-grained calcite nodules.

The fossils Ayers (1952, p. 16) mentions as occurring in the Pleistocene deposits west and south-west of Rahmu could possibly have been derived from the Jurassic sediments. Numerous poorly preserved lamellibranchs were seen during the present survey in parts of the base of the Shangalla Limestones and have obviously been acquired from the underlying Mesozoic sediments.

Gypsum only rarely occurs along the base of the Shangalla Limestones but further east at Amingure similar limestones are underlain by extensive gypsum and selenite, while gypsiferous deposits, presumably of the same age, patchily cover the low hills of the Mandera Series in the Dabeit area. Further east the low outcrops south of Gingo are strewn with large green acicular gypsum crystals, all that remains of a former fairly extensive gypsiferous deposit in that area. At the same elevation, numerous pebbles and cobbles derived from the Borahra deposits and Basement System quartzite occur in the lowest part of the calcareous crust capping the small hill four miles west of Mandera.

On the Kenya-Somalia border, 14 miles south-west of Mandera, a small outlier of Mandera Series is capped by bedded limestones and cherts that are considered to be of the same age as the Shangalla beds. The chert bands, which display a sponge-like structure, the cavities being in-filled by white calcite, are concordant with the stratification and give rise to resistant brown horizons.

The sedimentation of the Shangalla group commenced with fluvial conditions interspersed by droughts, and was followed by the slow accumulation of limestones and cherts in parts, in shallow lacustrine environments. The contemporaneous deposition of chert and limestone in the east probably indicates the mingling of salt and fresh waters (Twenhofel, 1950, p. 409). The physiographical position occupied by the Shangalla Limestones and associated rocks suggested that they were deposited during the first inter-pluvial period and that, therefore, they are of lower Pleistocene age.

(5) DEPOSITS OF KAMASIAN-KANJERAN AGE

During the Kamasian pluvial period a distinct terrace was formed along the Daua river at an altitude of 30 m. above the level of the present river bed. Mandera and Rahmu are situated on this shelf, which is now almost totally covered by red-brown sandy soils. Some twenty feet below the surface a calcareous crust consisting of numerous concretions of kunkar limestone has been forming since pre-Kanjeran times. In the valley north-east of Mandera this layer of nodules has preserved some outliers, the height of which was at first thought to indicate another river terrace. At Rahmu the calcareous deposits underlying the sandy soil merge into a soft chalky bed which is extensively exposed along the Lugh Afad, one mile east of Rahmu. Further west, in the Gingo area, a partly consolidated ferruginous sand occurs on the 30 m. terrace and probably dates back to the Kamasian-Kanjeran inter-pluvial.

During the second inter-pluvial period sediments, mostly of a calcareous nature, were deposited along the Daua valley where the lower reaches of the tributaries were submerged and where fairly quiet deposition took place. The sediments are pale grey calcareous silts and marls, approximately 30 feet thick, that become gritty nearer to the Daua river. In the Lugh Borotula, four miles west of Rahmu, they are overlain by a conglomerate with well-rounded quartzite pebbles and cobbles. Seven miles west of Rahmu an artifact was found within these sediments and was identified by Dr. L. S. B. Leakey as of the Kombewa technique, which he ascribes to the early Kanjeran. The siltstones and marls also contain numerous gastropods which were identified at the Coryndon Museum. One specimen is certainly a *Limicolaria* and there is little to distinguish it from *L. martensiana*, a species which occurs throughout East Africa and has innumerable races. There are also tapering shells possibly belonging to a species of *Melanoides*.

At Melka Bila, 21 miles west of Mandera, a friable grey calcareous grit, that must be included with the second inter-pluvial deposits, occurs along a ledge just below the 30 m. terrace. Bedding is not evident but the rock is fissile to some extent and displays darker and lighter-coloured streaks on freshly fractured surfaces. Under the microscope the rock (16/111) is seen to contain angular clastic grains up to one mm. across, consisting of remarkably fresh microcline, orthoclase, perthite, sodic plagioclase, and quartz, with less abundant and smaller grains of hornblende, epidote, sphene, magnetite and flakes of biotite, muscovite and chlorite cemented by clear crystalline calcite.

The gypsite which occurs along the Daua valley in the vicinity of Mandera at an elevation of 20 m. above the river bed was also probably deposited during the second inter-pluvial period.

(6) THE EL WAK BEDS

The southern extremity of the area includes a sector of the El Wak depression, where there are deposits in which the water-table occurs at a relatively shallow depth. Although there are a number of wells yielding brackish water in the vicinity of El Wak, none exist in the part of the depression within the present area, but mounds with adjacent hollows and pits are often encountered and indicate that a search for water was made in the past. Other small natural depressions caused by local sinking of the sediments are also numerous. El Wak fort is situated on a gypsite deposit which is at least 70 feet thick and bordered by a wide rim of kunkar limestone. The gypsite and marginal limestone are considered together as the El Wak Beds (Baker and Saggerson, 1958, p. 33).

The gypsite crops out as soft dead-white exposures that give rise to fine dark grey soils. Wells to a depth of 70 feet in the middle of the basin have failed to reach its base. The unweathered gypsite is usually grey in colour and contains approximately 75 per cent gypsum (Baker and Saggerson, 1958, p. 41). No bedding was observed but the formation of horizontal selenitic ribbons, which are sometimes quite clear though normally coloured by the inclusion of argillaceous matter, sometimes gives rise to an appearance of bedding. The gypsite effervesces slowly with cold dilute hydrochloric acid, indicating that a small amount of carbonate is present as impurity.

The surface limestone encircling the gypsite forms a border varying from three to eight miles in width and is possibly still expanding as more limestone is deposited, when carbonated waters come in contact with saturated solutions in or on gypsite. In hand-specimen (24/1) the limestone is a buff-coloured fine-grained rock with small veinlets of partly translucent carbonate. The microscope reveals a fine-grained crystalline aggregate of calcite containing a few small scattered angular clastic grains and irregularly arranged dusky crustiform growths that usually surround clear crystalline calcite. The surface limestone is thought to mask an impervious calcareous layer which forms the base of the El Wak deposits. Poborski (1954, p. 987) notes that in associations of gypsum with calcium carbonate, calcium carbonate has generally been precipitated first with evaporation until conditions of equilibrium were re-established and then, with continued evaporation, mixtures of both calcite and gypsum. The postulated concealed beds would explain the perched water-table in the basin and extensions of similar sediments would provide a possible source for the isolated occurrences of kunkar limestone apparently resting on essentially non-calcareous rocks in low-lying parts as far north as Damassa. It is thought that the El Wak beds were deposited within the restricted basin in which El Wak lies by the repeated evaporation and precipitation of calcium sulphate from a body of water, the lack of bedding possibly indicating a paludal environment where, also, no living animal could tolerate the high concentration of sulphates.

Dixey (1948, pp. 9-10) tentatively ascribed a Tertiary age to the El Wak beds, a view that Ayers (1952, p. 15) accepted. Baker and Saggerson (1958, p. 34) however, believed that the deposits are probably upper Pleistocene in age. During the present survey it was found that the base of the El Wak sediments is rather lower than the end-Tertiary peneplain, which would necessarily date the beds as post-Tertiary. It seems possible that the deposits are still increasing in extent, and may have been initiated as early as Lower Pleistocene, the major increases in growth taking place during the inter-pluvial phases of the Pleistocene. In the stratigraphical table on p. 45 the beds are shown as possibly upper Pleistocene in conformity with the opinion expressed by Baker and Saggerson, though, as yet no strong evidence has been found to indicate that deposition was restricted to that period.

(7) LOWER TERRACE SEDIMENTS AND SOILS

Remnants of a 10 m. terrace occur along the Daa valley and are thought to represent the Kanjeran pluvial phase. They form small flat-topped mounds composed of fine-grained yellowish brown soil sediments, and occur on the flood valley of the Daa river. The dissection of the 10 m. terrace probably took place during the Gamblian pluvial, which brought the river down to the flood valley level, which is 3 m. above the present river bed. The sediments of the flood valley are fine and grey with some admixture of sand in parts, and become waterlogged during heavy rains. The flood valley area is often covered by dense vegetation which is dominated by doum palms that fringe the river along its entire course. The river has cut its present course during and since the Makalian and Nakuran pluvial phases and has deposited sand banks along its course.

The major part of the Mandera-Damassa area is covered by reddish-brown sandy soils derived mainly from the weathering of the sandy Marehan Series, being alluvial in the vicinity of Mandera and largely residual further south. The thickness of the soil cover varies considerably. The soil derived from the Jurassic limestones in the north-west part of the area is finely divided and ranges from brown to grey in colour. Similar brown dusty soils occur in small scattered patches in all parts of the area where drainage is poor, the larger being indicated on the map in the vicinity of Mandera. Ayers (1952, Map No. 4) refers to the latter localities as "mudflats".

Here may also be included mention of a thin extensive kunkar deposit south-west of Wilderri, on the Awarra plain. It was probably formed as a result of the evaporation of a Recent swamp.

VI—STRUCTURE

The structural elements of the area fall into two sets, one with general N.E.-S.W. strike and the second with N.W.-S.E. strike, the former being the more important (see Figs. 4 and 5).

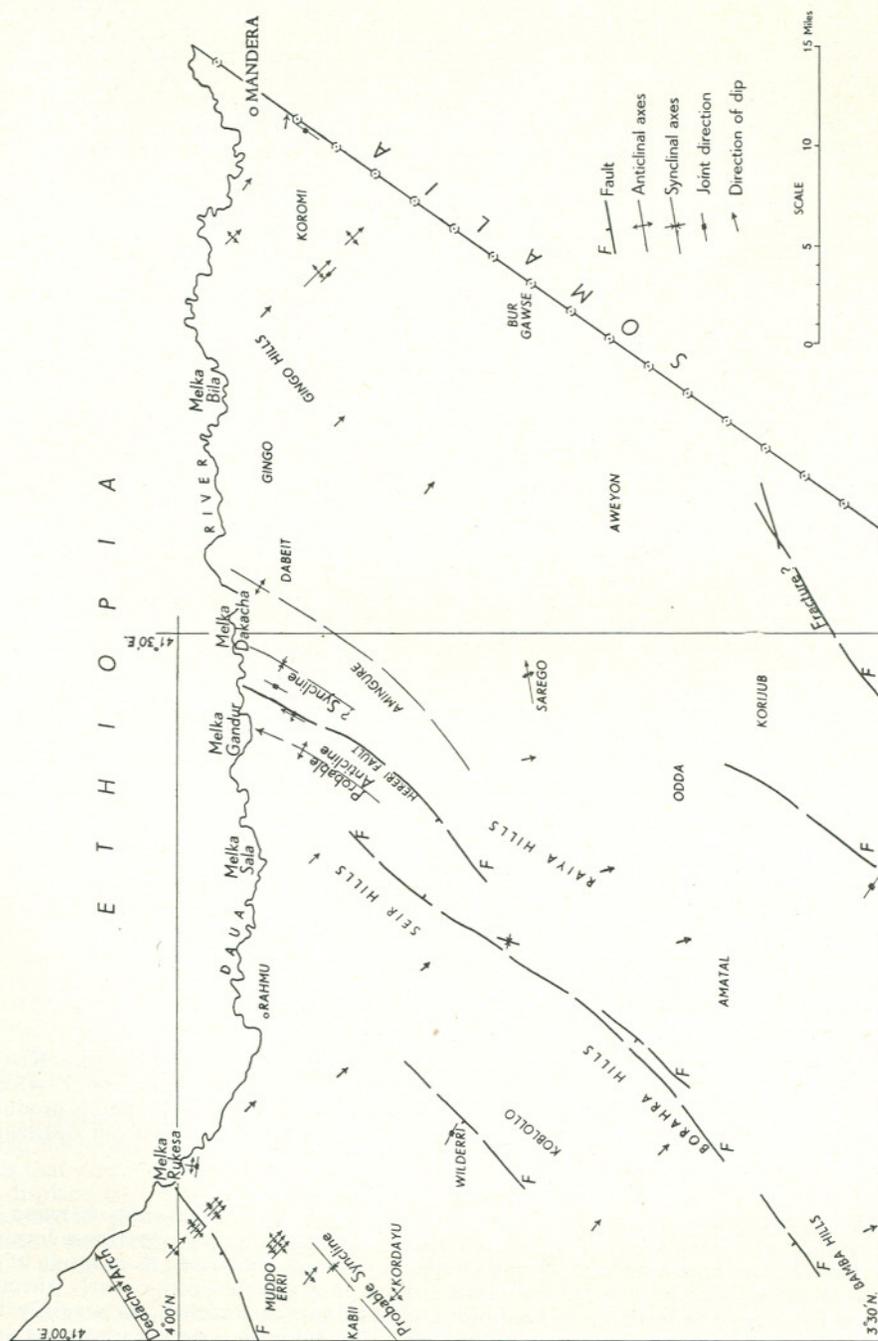


Fig. 4.—Structural map of the Mandera area.

The regional dip of the Jurassic sediments is normally 1° to 2° to the south-east and that of the Marehan series 3° to the south-south-east. In parts the dips have been disturbed by subsequent mild folding and by intense faulting. The most important structure in the

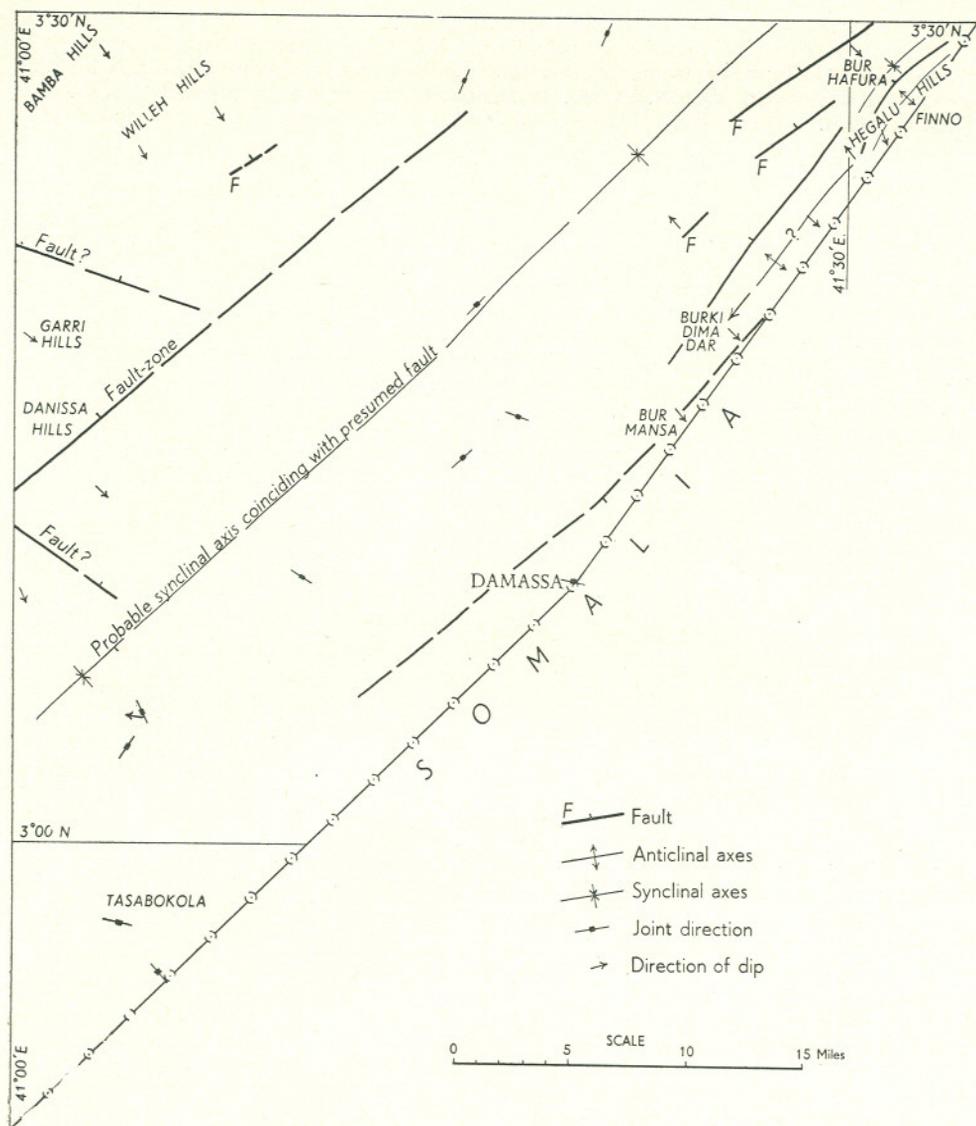


Fig. 5.—Structural map of the Damassa area.

area is that forming the Hegalu hills which, however, is mainly exposed east of the Kenya-Somalia border (see large scale map of the Hegalu hills, at end). Ayers (1952, pp. 17-18 and Fig. 6) deduced that the "Hafura structure", which in fact forms the Hegalu hills, is produced by a horst, but failed to identify some important features because he did not distinguish between the Manderan and Marehan Series in that area.

The Hegalu horst, which has yielded further proof of the unconformity between the Jurassic and Cretaceous Systems as well as evidence of faulting during uppermost Jurassic-lower Cretaceous times that only disturbed the Cretaceous sediments as a result of rejuvenation, is bounded by two parallel faults striking in a general north-easterly direction (Fig. 5). The sediments bounded by the faults are folded into an anticline, the axis of which is a sinuous line approximately parallel to the faults. The sediments are more intensely folded in the north-eastern part of the hills in Somalia where steep dips were recorded, but dips are lower in the south-west and eventually at Finno, where the axis plunges at a low angle to the south-south-west, are hardly noticeable.

When tracing the western Hegalu fault from Finno towards the north-east, it became obvious that not one fault alone is involved but a series of faults, each following a N.E.-S.W. trend for some distance and then diverging in a northerly direction, being replaced along the main trend by another fracture which, in its turn, eventually diverges in a northerly direction.

The base of the Hegalu hills on their north-western side in the region of Finno and in the north-eastern part of the hills in Somalia is composed of typical argillaceous limestone of the Dakacha Limestones conformably overlain by the Mandera Series, which itself forms the lower part of the hills in the intervening stretch. The Mandera Series is 750 feet thick at Finno and 200 feet thick at Mata Arba in the north-east and is unconformably overlain by the Marehan Series. These facts alone point to an unconformity between the Jurassic and Cretaceous Systems, but the angle of 4° between the bedding of the Mandera Series and the base of the Marehan Series displayed on the hillside two miles north of Finno proves the unconformity conclusively (Plate IV a).

The faults along the western flank of the horst flexed the Danissa Beds abutting against them, and by reversing the dip produced a synclinal fold with an axis parallel to and just west of the faults. Along the eastern side of the horst an increase of dip to the east occurs in the Danissa Beds in the proximity of the limiting fault.

Finno hill is capped by a thickness of approximately 50 feet of Marehan Sandstones, while Danissa Beds of unknown thickness occur west of the fault, more than 1,000 feet below. It has already been recorded that the total thickness of the Danissa Beds in the area does not exceed 400 feet, and therefore it can be calculated that the displacement of the Cretaceous sediments along the western fault at Finno does not much exceed 500 feet. When the Daua Limestone Series-Mandera Series junction is considered, however, it is seen that the total throw of the fault probably exceeds 1,500 feet, but may be much greater depending on the thickness of the unexposed Mandera Series to the west of the fault. In addition, a 4° angle of unconformity between the Jurassic and Cretaceous Systems is impossible on the basis of their undisturbed regional dips and therefore movement must have taken place prior to the deposition of the Marehan Series, a movement that here involved a displacement exceeding 1,000 feet along faults.

The movement along the faults must have been differential. From the disposition of the sediments it can be deduced that movement at the end of Jurassic times must have involved a greater displacement along the north-easterly part of the horst, resulting in a south-westerly dip of the Jurassic sediments. This dip was re-modified by a renewal of movement along the faults after the deposition of the Cretaceous beds, when displacement was much greater in the south at Finno than in the north-eastern part of the horst. It is believed that it was at this stage that the shear-faults described above were produced. Evidence for the later phase of movement is found in the fact that the displacement of the Cretaceous sediments is much less further to the north-east than is evident at Finno. The lesser thickness of Mandera Series at the northern end of the horst indicates the removal of a greater amount of Jurassic sediments during the Jurassic-Cretaceous interval from that part as compared with the region of Finno. Minor movement along the faults may have taken place during the Cretaceous sedimentation but it is believed that the main rejuvenation probably occurred during upper Cretaceous times. Another feature of the Hegalu hills that could have been produced by the variation of movement along the faults is the gentle cross-folding, as delineated on the map.

Except at the northern end of the hills where erosion has exposed lower levels in the horst, the fault along the eastern flank has not been observed, but steep dips in the Danissa beds that cannot be far from where they abut against the fault indicate the flexing produced by displacement. It is again encountered at Bur Mansa, where the silicified fault breccia described on p. 43 occurs. Silicified sandstone outcrops further to the south-west probably indicate the southerly extension of the fault. At Burki Dima Dar a confusing set of small faults probably indicates the southerly termination of the main anticlinal fold of the horst.

Faults of smaller throw west of and parallel to the Hegalu structure can be detected only by a linear arrangement of small silicified sandstone outcrops. A fault with a calculated throw of nearly 200 feet traverses the area immediately west of Bur Hafura and causes the exposure of the lowest beds of the Marehan Series in the hill. Ten miles further south-west a north-westerly dip is affected by a fault to the east, so accentuating the gentle syncline that appears to occur further west. The synclinal axis coincides with a fault which defines the

south-eastern end of the Danissa hills, the fault having a downthrow to the south-east. Along the northern extension of this synclinal axis no displacement of the Cretaceous sediments is apparent, but dark lines on the aerial photographs of that part, as indicated on the map south-east of Korijub (Fig. 4), appear on the ground as white chert with numerous vesicles and a little carbonate, and are taken to represent the traces of fractures.

Another parallel fault-zone extends from the heart of the Danissa hills to the north-east and defines the south-eastern limit of the Marehan Sandstones of the Willeh hills. The north-westerly striking fault shown in the Danissa hills (Fig. 5) is apparent from stratigraphical evidence only, and a fault with a generally similar strike between the Garri and the Bamba-Willeh hills is postulated on the same grounds.

South and south-west of Dakacha (Fig. 4) an anticlinal fold with N.E.-S.W. axis causes the reappearance of the Dakacha Limestones east of the Daua Limestone Series-Mandera Series junction, and is indicated further south by the distribution of the Mandera Series on the Daua Limestones. To complete the structural picture in the north-central part of the Mandera area a synclinal fold or monoclinical terrace is postulated in the vicinity of the Durer Tadere hills, about two and a half miles west of the anticline.

About two miles west of the Durer Tadere fold the Hereri strike fault cuts the Jurassic rocks. Ayers (1952, p. 19) stated that the Hereri fault has an upthrow to the west with a vertical displacement of not more than 100 feet. During the present survey, however, the discovery of a 50-ft. thick outlier of Marehan Series to the west of the fault in the northern Harahra hills proved that the down-throw is to the west and that there is a vertical displacement of the Cretaceous sediments of approximately 300 feet. The displacement further south is considerably less and the fault eventually peters out on the western side of the Raiya hills. Small folds occur parallel to the Hereri fault where the Seir limestones abut against it (Plate IV *b*).

A long fault with down-throw to the east stretches along the eastern flank of the Seir hills and continues south-westwards along the eastern flank of the Furfurso and Borahra hills, forming the contact between the Seir Limestones and Hereri Shales or the Dakacha Limestones. Three faults were also mapped a little east of the line of this fault, between the Aliwondo valley and the Bamba hills. The southernmost of these down-throws to the west, but disturbs the Marehan Series in the northern Bamba hills only slightly. There are large accumulations of boulders of Marehan Series rocks on its down-throw side when it passes away from the hills. The beds on both sides of the small fault dip in the Aliwondo valley towards the fault plane, and it is thought that the opposing dips probably result from caving of the roof of a water channel along the fault plane.

Between the Hereri fault and the complementary fault along the Seir hills an anticlinal fold is postulated, though there is almost no evidence for it on the Kenya side of the Daua river. On the Ethiopian side, however, the closure of an anticline on the same line is distinct on the aerial photographs.

A fault of small throw, again with north-east strike, can be seen cutting across the south-eastern part of the Wilderri exposures. Recrystallization of the limestones has occurred adjacent to the fault.

The opposing nature of the plunges of minor N.W.-S.E. folds at Kordayu and Muddo Erri are taken to indicate the existence of a synclinal fold with N.E.-S.W. axis in the vicinity of Kabii. Further west a fault of minor displacement follows the main tributary valley of the Lugh Rukesa, producing "steep" dips along the eastern flanks of the hills. Subsidiary fractures are filled by striated coarsely crystalline calcite. South-east of Rukesa a small W.N.W.-E.S.E. fault possibly separates a low anticline north of the road from the unfolded sediments south of the road. Some evidence for it is perhaps provided by a higher than normal dip to the north-west recorded in the vicinity of its presumed trace.

The Dakacha arch, described by Ayers (1952, pp. 9 and 18), flexes the sediments into a wide anticlinal fold with N.E.-S.W. strike in the extreme north-western part of the area. The dips along the flanks of the anticline are difficult to appreciate on the ground, but the fold can be seen in the escarpment of Murri Limestones on the Ethiopian side of the Daua when it is viewed from Kalkach Uranni. The gentle arching has, in fact, caused a higher than normal dip to the south-east, east of Kalkach Uranni, where the dip is approximately 1° more than the regional dip of the Jurassic sediments.

Folds of small wavelength and amplitude with a south-easterly plunge disturb the Mandera Series in parts (Plate III *a*). The anticlines are often fractured along their crests with the fractures dipping at steep angles to the south-west. A series of anticlines and synclines with axes plunging to the south-east also occurs in the Muddo Erri-Melka Rukesa section of the area. Comparable folds in the area further west (Thompson and Dodson, 1958, p. 31), where they have been described as occurring in the direction of major structural trend, have a greater amplitude.

Variations of the smaller folds were found at Kordayu where the plunge of an axis is to the north-west and at Sarego where the strike is a little north of east and the plunge easterly. It will be noted that the strike of the latter fold converges with the Hereri fault and its neighbouring folds (Fig. 4).

Well-developed vertical joints occur in most exposures of the Mesozoic rocks, their directions being normally in accordance with the structural pattern of the area. The major direction is again along the strike, with the less frequent direction at right-angles to it.

It is thought that the N.E.-S.W. folds probably resulted from gentle compression in a N.W.-S.E. direction and that with relaxation, tensional stresses developed resulting in gravity faulting along the strike. It will be noted that the direction of compression suggested is almost at right-angles to that postulated in neighbouring areas (Saggerson and Miller, 1957, p. 36; Thompson and Dodson, 1958, p. 30; Baker and Saggerson, 1958, p. 38) where, however, as in the present area, there is evidence of compression or effective compression in two directions at right-angles. In the Mandera-Damassa area it is not clear which direction should be regarded as the major, though it is possible that the N.W.-S.E. structures may have developed as a result of sag in the basin of deposition rather than as a result of compression.

VII—GEOLOGICAL HISTORY

The lithology, structure, palaeontology and stratigraphic sequence of the sediments of the Mandera area permit the following interpretation of its depositional history.

The Murri Limestones, the oldest sediments in the area, were deposited during a period when the Jurassic (Bathonian) sea was rapidly encroaching onto the eastern margin of the continent of Africa, their lower parts indicating rapid and uniform deposition of limestone, perhaps keeping pace with the rise of sea-level. Bedding in these sediments originated mainly as a result of the entrance at times of small amounts of argillaceous and ferruginous material. The conditions of deposition were at first unfavourable for the preservation of animal remains in the sediments. Later, deposition slowly caught up with the rate of subsidence and is reflected in the appearance of argillaceous beds and the presence of a small marine fauna indicating shallow-water conditions. The uppermost beds of the Murri Limestones are composed mainly of shell fragments and oolites and suggest that they were formed as shell gravels, by wave action or strong currents.

The expanding sea extended a gulf into north-eastern Kenya which was part of a large shelf sea encroaching on Ethiopia and the Horn of Africa as well as to the north onto parts of Egypt (Sadek, 1922, p. 1040) and southern Arabia (Little, 1925, pp. 116-117). To the south the ocean infringed on the eastern margin of Africa, depositing sediments along coastal Kenya and Tanganyika, and submerged the western flank of Madagascar.

The Rukesa Shales of Callovian times were deposited in a shallow-water environment, as can be deduced from their fauna and the presence of some coarser clastic material. Bedding in them resulted from the alternate supply of argillaceous and calcareous material or sand. It is evident that the rate of subsidence was balanced by deposition during lower Callovian times, and that very shallow-water conditions existed during the uppermost Callovian. A forecast of such conditions is manifested by the local development of intraformational conglomerate at Muddo Erri, which was later followed by the deposition of shell detritus associated with oolites, and culminated in the formation of calcareous siltstones that were probably deposited in a littoral environment in which graded bedding and cross-bedding could be developed.

Between upper Bathonian and upper Callovian times the preservation of relics of the fauna increased with the more favourable conditions then existing and resulted in such fossiliferous horizons as those encountered at Muddo Erri and Kulong. The littoral conditions of the uppermost Callovian were most unfavourable. A new fauna appeared at the time of deposition of the Rahmu Shales, which were deposited in comparatively shallow

water, as is indicated by the presence of interference ripple-marks and the occurrence of such fossils as *Mytilus*, *Lopha* and thick-shelled brachiopods. The prevailing conditions were favourable to life and an increasing number of fossils are found representing the improved environment, and culminating in the deposition of such fossiliferous horizons as those occurring at Wilderri and Dussé. The reason for the lack of fossils in higher beds is rather obscure, but may be due to the very shallow-water conditions that repeatedly prevailed during upper Oxfordian times, as is substantiated by the gregarious communities of *Lopha* at Wilderri and Dussé. The same species reappear in the Upper Seir Limestones, although in greatly reduced numbers.

Argillaceous beds also mark the Oxfordian in Somalia, alternating sandy beds being probably correlatable with the calcareous siltstone horizons in the Seir Limestones, which increase in thickness towards the south-west and probably pass into the Golberobe Beds (Saggerson and Miller, 1957, p. 13) of the area to the south-west. It is thought that the calcareous siltstones indicate successive littoral conditions during the upper Oxfordian in the Mandera area and it is worthy of note that Baker and Saggerson (1958, p. 19) described a slight unconformity at the base of the Golberobe Beds in the El Wak area. It is also noteworthy that Hirtz (1949, p. 32) records a regression at the close of the Argovian (upper Oxfordian) in south-western Madagascar.

The gypsum contained in the Hereri Shales points to an arid or semi-arid climate during part of the Kimmeridgian stage and to at least one period when stagnant conditions may have prevailed. Numerous fossils occur in the shales above the gypsiferous beds with reversion to normal marine sediments and are indicative of an environment favourable to animal life. No major change took place during the deposition of the Dakacha limestones, although local sandy beds were laid down, but a reduced fossil assemblage is again noticeable and, apart from large gastropods and some oysters, no fossils are encountered until the high beds are reached that represent the beginning of the regression that ushered in Tithonian times.

Thus, it can be postulated that during the deposition of the Daua Limestone Series of this area, the Jurassic sea was expanding (westwards) up to upper Bathonian times, after which deposition, with slight oscillations of sea-level, kept pace with the slow subsidence of the eastern margin of the African continent up to the close of the Kimmeridgian. There is evidence of slight regressions towards the close of the Callovian and during the upper Oxfordian and middle Kimmeridgian.

During Tithonian times a regression of the Jurassic sea, also taking place with a pulsating movement, left a wide and interesting range of sediments in its wake. The sudden onset of the conditions that prevailed during the deposition of the Mandera Series caused the death of communities of terebratulids, clams and crinoids in the quiet shallow water, their remains being preserved in the calcareous clay of the uppermost part of the Dakacha Limestones group. Subsequently along parts of the shore terrestrial cross-bedded sands accumulated and shales and silts were deposited in the sea, possibly in a lagoonal environment under arid or semi-arid conditions. The pulsating character of the regression gave rise to alternating marine and lagoonal environments, most of the sediments being deposited in very shallow water. In this connexion it should be recalled that the Mandera Series is characterized by glauconite which sometimes imparts a green colour to the sediments, but is never abundant enough to form greensands. It may be taken to indicate deposition under stagnant marine conditions, when little sediment was being deposited. The sandstone beds, so variable in thickness along the strike, no doubt often represent off-shore bars, though in the case of the massive sandstone horizon of the Jirma Beds, for example, perhaps wind action contributed to its formation. Sandstones and coarse siltstones formed prominent deposits along the shores of the basin, grading laterally to the north-east and east into fine silts and shales.

Gypsum, usually present below massive sandstone horizons in the Mandera Series, indicates desiccation of parts of the area, probably in lagoonal phases which were interspersed with stages of slight transgression when mostly limestones, shales and silts were deposited. Ripple-marks are prevalent throughout the Mandera Series, and are nearly always of a type that indicate that there were fast-flowing currents at the time of their formation. The conditions of deposition of the Mandera Series were on the whole unfavourable for the preservation of animal remains, but marine fossils occur in a few thin, but remarkably persistent horizons, indicating minor transgressions of the sea. Fossilized plant remains indicating estuarine or on-shore conditions, occur in sandy beds at various elevations in the succession but are poorly preserved and beds containing plant remains are usually not persistent along the strike.

The regression of the sea during Manderan times took place in a north-easterly direction and its ultimate expression is considered to be the deposition of the Main Gypsum, including some shaly and marly beds, in northern Ethiopia (Taylor, 1948B). The progress of the regression is expressed in southern Ethiopia, where Aubry found a 600-foot thick succession of sandstones, marls and gypsum capping the main Jurassic succession (Daqué, 1910, p. 40). The regression is also indicated by sandiness towards the top of the limestone-sequence of Somaliland Protectorate, where in some parts, there are isolated basins that include evaporite deposits (Somaliland Oil Exploration Co. Ltd., 1954, p. 7).

It is at this stage of continental emergence that the small plications in the Manderan Series and the small folds in the limestones of the north-west part of the area may have formed. S.S.E.-N.N.W. compression during early Cretaceous times resulted in mild folding along N.N.E.-S.S.W. axes. Subsequent release of pressure is believed to have led to gravitational faulting along strikes similar to those of the folds, giving rise among other structures, to the Hegalu horst.

A period of continental erosion and denudation succeeded the emergence, resulting in the planing off of large tracts of the Jurassic succession. During Wealden times subsidence again allowed the sea to enter what is now north-eastern Kenya. The Cretaceous sea spread along similar lines as the Jurassic sea but never reached the same extension. Oscillations of sea-level gave rise to alternate marine and estuarine deposits, in which ripple-marks and cross-bedding are the rule rather than the exception, during the deposition of the Danissa Beds. Bright colours are prevalent especially towards the top of the sequence and are taken to indicate the gradual desiccation of the area during the time in which those beds were laid down. The life of the time is represented by marine fossils in some beds and by beds containing plant remains, but finally with emergence and the invasion of the basin by terrestrial sands, sediments were left that contain no traces of the life of the period.

During the first part of the Marehan Series sedimentation the Hegalu horst stood as an island in the Cretaceous sea but was gradually buried by sediments, culminating in the thin cover of beds of the upper part of the Marehan Series.

Rejuvenation of the N.N.E.-S.S.W. striking faults took place after the cessation of Cretaceous deposition, presumably during Upper Cretaceous times, but it is possible that minor movements along the faults occurred at intervals throughout the Cretaceous period.

No sediments representative of the Upper Cretaceous or Lower Tertiary are known in the area and, if deposition during those times took place, all record has since been removed by denudation which has been the main factor in shaping the area since the Marehan Series was deposited. A stable phase ending in the middle Tertiary can be recognised by the sub-Miocene peneplain that bevels the Bamba-Garri hills in the west and the Hegalu hills in the east. A phase of uplift followed and the intermediate erosion surface developed, probably in Miocene times. Following the initiation of a new base-level denudation continued during the rest of the Miocene and the Pliocene, culminating in the formation of the end-Tertiary peneplain.

There is evidence that there were some lakes in the area in Plio-Pleistocene times, when the Bohraha beds were laid down. During the lower Pleistocene an erosion surface was formed at an altitude of about 60 m. above the present level of the river Daua. In the succeeding inter-pluvial phase there were discontinuous shallow lakes in parts of the area, and gypsum and chert were deposited in them. In other parts the erosion of the higher ground led to the deposition of pebble beds, conglomerates and grits, the phase of accretion terminating with the deposition of lacustrine limestones at Shangalla and Amingure. This was followed by a slight tilting of the area, manifested in the slope of the peneplains, that caused extensive dissection of the early Pleistocene deposits.

In the second pluvial phase of the Pleistocene a well-developed shelf 30 m. above the present Daua river bed was formed, followed in the subsequent interpluvial phase by the deposition of silty limestones, grits and conglomerates along the valley. From the sequence of these sediments it is possible to postulate that there was fairly quiet deposition at first, but that it was followed by turbulent floods when conglomerates and sometimes boulder beds were laid down. The third pluvial phase resulted in the formation of a terrace 10 m. above the Daua, which was dissected during the subsequent phases, which ended with the formation of the 3 m. terrace in the Gamblian pluvial. The present river-course of the Daua was incised during Recent wet phases, when sands were also deposited along it at certain parts. During these wet phases poor drainage in the Awarra area south-west of Wilderri resulted in the formation of a swamp which, with subsequent evaporation, left an extensive kunkar deposit.

VIII—ECONOMIC GEOLOGY

1. Oil

The geological survey of the sediments of north-eastern Kenya is of considerable interest in connexion with the search for oil. Although no oil or gas seepages or bitumenous outcrops were discovered, several other features of the succession are attractive from the point of view of the occurrence of oil and sufficient to warrant more extensive exploration.

In considering the areal extent of the Mesozoic sediments, which naturally would affect the chances of discovering oil, it is of importance to recognise the continuation of these sediments in Ethiopia and the Somalias, and that the sediments of north-eastern Kenya constitute a small portion of a sedimentary succession of wide extent.

Approximately 4,000 feet of marine limestones occur within the Jurassic succession and there is unlikely to be a scarcity of oil source-rocks in them. Ayers (1952, p. 20) enumerates these possible sources of oil. The apparent absence of suitable reservoir rocks among the limestones, however, reduces the value of these sediments as potential oil-bearing strata, though the calcareous siltstones of the Seir Limestones which grade into non-calcareous sandstones to the south-west, as well as the highly jointed limestones that occur within the calcareous shaly strata (Plate I *a*) may prove to be suitable reservoirs. Effective seals can be found in many of the shaly horizons occurring throughout the succession.

In evaluating the area the most important feature to consider is the overlap of Cretaceous sediments onto the Jurassic succession. The dolomitization of the limestones below this junction has already been discussed and the dolomite should be a good reservoir rock. In addition, the sandy horizons of the Mander Series, with distinct lateral variations in grain size and thickness, would form good reservoir rocks. Although the sandstones usually have an increase of porosity up-dip their lens-like and wedging nature improves their possibilities as reservoir rocks, especially where they are sealed by the impermeable shales of the lowermost Danissa Beds. It is doubtful whether the ancient shore-lines of the sea of Mander times were preserved through the Lower Cretaceous emergence, but it is possible that successive slight transgressions by the Mander sea during its oscillatory withdrawal may have covered shore-lines with sediments that shielded them from erosion during the Lower Cretaceous.

Apart from these stratigraphic traps, important structural traps also exist in the anticlinal and faulted structures of the Hegalu horst and the Dedacha arch, while the many faults, some with appreciable throw, constitute potential oil traps.

Two wells have been drilled in Ethiopia by the Sinclair Petroleum Company (Hedberg, 1951, p. 1608 and 1954, p. 1477); the first, in easternmost Ethiopia, was abandoned at a total depth of 10,127 feet, while the second, drilled near Galladi in the Ogaden, was suspended when plugged back to 8,056 feet from a total depth of 9,081 feet.

Sediments ranging from Triassic to Lower Cretaceous in age constitute prolific oil producers in the Middle East. Lees (Illing, 1953, p. 69) states that the most prolific oil reservoirs of Saudi Arabia, Bahrein and Qatar are in Upper Jurassic beds in which several limestone members are separated by anhydrite and shale, and that the Arabian foreland oilfields (*op. cit.*, p. 68) occur in a zone of gentle folding where the demands on the efficiency of seal horizons are not great and thin shale members or single anhydrite beds can be completely effective.

2. Water

The most vital and immediate problem of the population of the Mander area is that of water-supply. The only permanent water-supply in the area is the Daua river which receives most of its water from the Abyssinian Highlands and flows for only part of the year. Water can, however, always be obtained from the river-course by digging in the sandy bed when the flow has stopped, and therefore the population migrate to the vicinity of the Daua during the dry seasons. Small amounts of water can also be obtained almost throughout the year in the sandy river-bed at Muddo Erri where the solid limestone valley is choked by boulders and sand.

During the rainy seasons water collects in rocky pools in the surroundings of the hills and in the numerous pans in the southern part of the area but, owing to the high rate of evaporation, such places have water only for a limited period which is, however, often extended by the digging of small wells in the bottoms of the depressions.

The streams are all influent and the water-table should be considerably higher in the vicinity of the Daua river than elsewhere in the area. The green vegetation along the lower reaches of the main ephemeral streams draining into the Daua indicates a shallower water table along those parts.

Good sites for dams are often encountered in the vicinity of the larger hills but owing to their inaccessibility the cost of building dams there would be prohibitive. There is an excellent dam-site at Melka Gandur where the Daua has incised deeply into the Seir Limestones, forming a narrow valley with high cliffs on both sides. A dam along the frontier might, however, involve international complications.

The alternating limestone and shale members of the Daua Limestone Series in the north-west of the area should contain larger reserves of water, especially where the succession has been disturbed by folding and faulting. Further to the east the sandstone horizons of the Mandera Series, usually intercalated in shales or mudstones, are obviously good aquifers. Towards the central part of the area in the vicinity of Odda and Korijub it is deduced from stratigraphical evidence that the Marehan Series does not exceed 100 feet in the thickness, and if the contact with the Mandera Series can be pierced, water can almost certainly be obtained at relatively shallow depth.

The silicified faults in the south are most impermeable and in conjunction with the south-easterly dip of the jointed Marehan Series, which would constitute the aquifer, could act as a reservoir for water provided the lower shaly horizons also prove to be impermeable. Another obvious locality for water boring in the same region exists along the synclinal fold west of the Hegalu hills. Even if water does not occur within the Danissa Beds, which are approximately 100 feet thick in this region, the sandstones of the underlying Mandera Series will undoubtedly contain water.

3. Building Materials

The materials required for the few administrative buildings erected at Mandera have all been derived from the sediments in the immediate vicinity of the township. Dimension stone is trimmed from the sandstone horizons of the Mandera Series, which also supplies the flaggy sandstones and siltstones used as paving stones, while lime has been obtained by the burning of the Pleistocene calcareous crustal deposits. Pleistocene gypsite in the Daua valley provided binding material for plasters. The lack of building material would hardly prove an obstacle to any development within the area as dimension stone, crushed stone for concrete aggregates and road-metal, as well as rock for making lime, can be acquired throughout the Jurassic succession. All the components of natural and Portland cement are within easy reach of Mandera.

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APPENDIX—(Contd.)

	Bathonian		Callovian		Oxfordian		Kimmeridgian	
	Murri Limestones	Rukesa Shales	Muddo Erri Limestones	Rahmu Shales	Seir Limestones	Hereri Shales	Dakacha Limestones	
" <i>Terebratula</i> " sp. nov.						+	+	
" <i>Terebratula</i> " sp. nov.						+		
<i>Cererithyris</i> cf. <i>dorsetensis</i> Douglas and Arkell		W						
<i>Loboidothyris</i> (?) cf. <i>aulites</i> (Stefanini)			W					
<i>Pryctothyris quillyensis</i> (Bayle)		A						
<i>Charltonithyris africana</i> var. Weir			W					
<i>Stiphrothyris</i> sp.			W					
<i>Lophrothyris</i> aff. <i>subsella</i> (Dacqué)							W	
<i>L.</i> (?) <i>senilis</i> Muir-Wood						+		
<i>Pseudoglossothyris sulcata</i> Muir-Wood		A	+					
<i>Avonothyris</i> (?) sp.		+						
<i>A. jordanensis</i> Muir-Wood			W					
<i>Bihenithyris barringtoni</i> Muir-Wood					A	A	A	
<i>B. weiri</i> Muir-Wood						A		
<i>Somalithyris</i> sps.		+		+				
<i>S. bihendulensis</i> Muir-Wood				+				
<i>Ornithella</i> sp.							A	
<i>O.</i> sp. cf. <i>humeralis</i> Roemer						A		
<i>Ornithella</i> sp. nov.					A			
<i>Berenicea somalica</i>						A		
<i>Nucula</i> sp.						A		
<i>Arca</i> (<i>Eonavicula</i> ?) sp.		+						
<i>Eonavicula</i> cf. <i>minuta</i> (J. de C. Sowerby)			+					
<i>Parallelodon egertonianus</i> (Stol.)					A			
<i>P. egertonianus</i> var. <i>crericostatus</i> (Stefanini)					A	A		
<i>Grammatodon</i> (<i>Indogrammatodon</i>) sp.								
<i>G.</i> (<i>Indogrammatodon</i>) <i>irritans</i> (Hennig)					+	+		
<i>G.</i> (<i>Indogrammatodon</i>) <i>stockleyi</i> Cox						+		
<i>Anomia</i> sp.							+	
<i>Mytilus alatus</i> Krumbeck = <i>M. jurensis</i> Roemer				A	A	A		
<i>Brachidontes</i> (<i>Arcomytilus</i>) <i>asper</i> J. Sowerby	+		+					
<i>B.</i> (<i>Arcomytilus</i>) <i>laimairensis</i> de Loriol				A				
<i>B.</i> (<i>Arcomytilus</i>) <i>subpectinatus</i> d'Orbigny						A	A	
<i>Modiolus imbricatus</i> J. Sowerby						+		
<i>M. subangustissimus</i> Dacqué							A	
<i>M. virgulinus</i> (Étallon)							+	
<i>M.</i> (<i>Inoperna</i>) <i>perplicatus</i> (Étallon)						A	A	
<i>M.</i> (<i>Inoperna</i>) <i>plicatus</i> J. Sowerby					+			
<i>Trigonia stefaninii</i> Venzo							+	
<i>Trigonia</i> sp.			+					
<i>Entolium demissum</i> (Phillips)			+					
<i>E. solidum</i> (Roemer)		W		A				
<i>Entolium</i> sp.					?			

APPENDIX—(Contd.)

	Bathonian		Callovian		Oxfordian		Kimmeridgian	
	Murri Limestones	Rukesa Shales	Muddo Erri Limestones	Rahmu Shales	Seir Limestones	Hereri Shales	Dakacha Limestones	
<i>Camptonectes lens</i> (J. de C. Sowerby)		W	+	+				
<i>C. cf. virdunensis</i> (Buvignier)		W					A	
<i>Chlamys baden-powellii</i> Weir		W						
<i>C. curviviarians</i> (Dietrich)	+	+	+			+	+	
<i>C. aff. palmyrensis</i> (Krumbeck)		W	W					
<i>C. (Radulopecten) cf. inaequistriata</i> (Phillips)					+			
<i>Radulopecten cf. erlangeri</i> Dacqué						A		
<i>Velata inaequistriata</i> (Fütterer)		W						
<i>Velata</i> sp.			W					
<i>Eopecten abjectus</i> (Phillips)		+						
<i>E. aubryi</i> (Douvillé)		+	+			A		
<i>E. cf. bonjourii</i> (de Loriol)					+			
<i>E. inaequistriatus</i> (Thurmann)						+		
<i>Lima (Plagiostoma) ? astartina</i> Thurmann						A		
<i>L. (Plagiostoma) cf. complanata</i> Laube				+				
<i>L. (Plagiostoma) harronis</i> Dacqué		A						
<i>L. (Plagiostoma) cf. jumaraensis</i> Cox				+				
<i>L. (Plagiostoma) cf. laeviuscula</i> (J. Sowerby)					+			
<i>L. (Plagiostoma) cf. rigida</i> (J. Sowerby)				W				
<i>L. (Plagiostoma) cf. schardtii</i> de Loriol				+				
<i>L. (Plagiostoma) strigillata</i> Laube				+				
<i>L. (Plagiostoma) subcardiiformis</i> Greppin		A						
<i>L. (Plagiostoma) subcardiiformis</i> Weir (non Greppin)			A					
<i>L. (Plagiostoma) sublaeviuscula</i>					A		A	
<i>L. (Plagiostoma) sp.</i>								
<i>L. (Plagiostoma) n. sps.</i>	+		+					
<i>Pseudolimea duplicata</i> (J. de C. Sowerby)			+			+		
<i>Ctenostreon proscideum</i> (J. de C. Sowerby)							+	
? <i>Ctenostreon</i> sp.						A		
<i>Ostrea cf. costata</i>						A		
<i>Ostrea</i> sps.				+			A	
<i>O. (Liostrea) contejean</i> Étallon							+	
<i>O. (Liostrea) dubiensis</i> Contejean								
<i>O. (Liostrea) sps.</i>	+	+	+			+		
<i>O. (Catinula) cf. ancliffensis</i> Cox and Arkell		+						
<i>O. (Gryphea) balli</i> (Stefanini) ?						A		
<i>Gryphea</i> sps.							A	
<i>Exogyra nana</i> J. Sowerby		W				A		
<i>E. vinassai</i>						A		
<i>Exogyra</i> sp. nov.				A				
<i>Exogyra</i> sps. indet.					+	+		
<i>Eligmus asiaticus</i> Douvillé			W					
<i>E. polytypus</i> Eudes-Deslongchamps			A					
<i>E. rollandi</i> Douvillé		+	+					

APPENDIX—(Contd.)

	Bathonian		Callovian	Oxfordian			Kimmeridgian	
	Murri Limestones	Rukesa Shales		Muddo Erri Limestones	Rahmu Shales	Seir Limestones	Hereri Shales	Dakacha Limestones
<i>E. rollandi</i> var. <i>laevis</i> Douvillé		A						
<i>Lopha costata</i> (J. de C. Sowerby)		A						
<i>L. gregarea</i> (J. Sowerby)		+		A	+			+
<i>L. marshi</i> (J. Sowerby)				A				
<i>L. solitaria</i> (J. de C. Sowerby)		A		A	+			
<i>Pteria</i> sp. nov.								+
<i>Oxytoma</i> aff. <i>expansa</i> Phillips						A		
<i>Meleagrinea</i> cf. <i>maltonensis</i>					A			
<i>M.</i> aff. <i>ovalis</i> (Phillips)					A			
<i>Meleagrinea</i> sps.					?	A		
<i>Gervillia</i> (<i>Gervillella</i>) aff. <i>aviculoides</i> J. Sowerby					A			
<i>Pinna stoliczkaia</i> Cox					A			
<i>Pinna</i> sp.					A			
<i>P. (Stegoconcha) g-mülleri</i> Krenkel					+			
<i>P. (Stegoconcha)</i> sp.				A				
? <i>Trichites suprajurensis</i> Krumbek					A			
<i>Astarte minima</i> Angelis d'Ossat (<i>non</i> Phillips?)			W					
<i>A. ovata</i> W. Smith						A		A
<i>Astarte</i> n. sp.					+			
<i>Astarte</i> ? sp.								
<i>Coelastarte</i> sp. (? <i>C. excavata</i> var. <i>asiatica</i> Douvillé)		A						
? <i>Opis michelina</i> Buvignier		A						A
<i>Trigonopsis</i> cf. <i>viridunensis</i> (Buvignier)		A						
<i>Anisocardia minima</i> (J. Sowerby)		+						
<i>Cypricardia (Pseudotrapezium)</i> aff. <i>cardiformis</i> Desh.						A		
<i>Lucina</i> cf. <i>lirata</i> Phillips		A				A		
<i>Lucina rugosa</i> Roemer								
<i>Lucina</i> sp.					+			
<i>Corbis lajoyei</i> d'Archiac				+	+			
<i>Fimbria</i> sp.		A						
<i>Quenstedtia</i> sp. nov.								+
<i>Quenstedtia</i> sp. (?)		A						
<i>Eocallista</i> ? sp.								+
<i>Cardium</i> (? <i>Protocardia</i>) <i>bannesium</i> Contejean						+		
<i>Protocardia</i> sps.		A		?	+			+
<i>Maclomya aequalis</i> Agassiz		+		+				
<i>M.</i> aff. <i>impressa</i> Mor. and Lyc.		A						
<i>M. rugosa</i> (Roemer)		W				+		+
<i>Ceratomya concentrica</i> (J. de C. Sowerby)		+		+		A		
<i>C. excentrica</i> (Roemer)						+		A
<i>C. wimmisensis</i> (Gilliéron)		A		A				
<i>Ceromyopsis</i> cf. <i>aequatorialis</i> (Müller)				W				
<i>C. kiliani</i> Rollier		+		+				
<i>C.</i> sp. cf. <i>C. somaliensis</i> Weir						A		

APPENDIX—(Contd.)

	Bathonian	Callovian		Oxfordian		Kimmeridgian	
	Murri Limestones	Rukesa Shales	Muddo Erri Limestones	Rahmu Shales	Seir Limestones	Hereri Shales	Dakacha Limestones
<i>C. aff. striata</i> (d'Orbigny)					+		+
<i>Pleuromya aff. solodurinensis</i> de Loriol					A		
<i>Pholadomya carinata</i> (Goldfuss)		A					
<i>P. hemicardia</i> (Roemer)							+
<i>P. inornata</i> J. de C. Sowerby		+					
<i>P. lyrata</i> J. de C. Sowerby		+					
<i>P. ovalis</i> (J. Sowerby)			+				
<i>P. protei</i> (Brongniart)		W					
<i>P. ragazzi</i> Pant.					A		
<i>Homomya gibbosa</i> (J. Sowerby) or <i>H. crassiuscula</i> Lyc.		A					
<i>Homomya</i> sp. nov.				+			
? <i>Myopholas acuticostata</i> (J. de C. Sowerby)					A		
<i>Cerromya</i> ? sp. nov.		+					
<i>Thracia depressa</i> J. de C. Sowerby					A		
<i>Straparollus</i> sp. indet.			+				
<i>Pleuromaria</i> ? sp.		+					
<i>Pseudomelania valfinensis</i> (de Loriol)					+		
<i>Ampullella</i> sp.						A	A
<i>Ampullospira eudora</i> (d'Orbigny)					+		
<i>Ampullospira</i> sp.							+
<i>Bourguetia striata</i> J. Sowerby					A		
<i>B. saemanni</i> (Opper)					+	+	
<i>Harpogodes oceani</i> (Brongniart)					+	+	
<i>H. cf. thirriae</i>						A	
<i>Harpogodes</i> sp.							A
<i>H. (Pterocera) aff. polypoda</i> Buvignier						A	
" <i>Aporrhais</i> " sp. indet.		+					
<i>Aporrhais</i> sps.			+		+		
<i>Nerinella</i> sp. indet.					+		
<i>Nerinea</i> sps. indet.		+			+		
<i>N. somaliensis</i> Weir ?						A	
<i>Trochalia depressa</i> (Voltz)					+		+
<i>Globularia</i> sps.		+	+				
<i>G. amata</i> (d'Orbigny)							+
<i>G. hemisphaerica</i> (Roemer)						+	+
<i>G. phasianelloides</i> (d'Orbigny)							+
<i>Cylindrites</i> sp. indet.		+					
<i>Acteonina</i> ? sp. indet.							+
<i>Nautilus</i> sp.				A	+		
<i>Paracenoceras</i> sp. nov. [cf. <i>P. dorso-excavatus</i> (Parona and Borarelli)]		+					
? <i>Dhosaites</i> cf. " <i>Macrocephalites</i> " <i>rabai</i> Dacqué					A		
? <i>Mayaites</i> sp.					A		

APPENDIX—(Contd.)

	Murri Limestones	Bathonian	Rukesa Shales	Callovian	Muddo Erri Limestones	Oxfordian	Rahmu Shales	Seir Limestones	Hereri Shales	Kimmeridgian	Dakacha Limestones
? <i>Epimayaites</i> aff. <i>lemoini</i> Spath								+			
<i>Perisphinctus</i> of the <i>plicatilis</i> group								A			
cf. <i>Perisphinctus</i> <i>achillus</i> d'Orbigny									A		
<i>Biplices</i> aff. <i>africanus</i> (Dacqué)							A				
<i>Aspidoceras</i> sp.							A				
<i>Peltoceratiodes</i> cf. <i>constantii</i> (d'Orbigny)							A				
<i>Belemnopsis</i> <i>tanganensis</i>							A	A	A		

A*—fossils listed in Report No. 22, Ayers.

W—fossils described by Weir *et. al.*

+—fossils collected during present survey.

APPENDIX—(Contd.)

	Bathonian					
	Murri Limestones	Rukesha Shales	Muddo Erri Limestones	Rahmu Shales	Scir Limestones	Hereri Shales
						Dakacha Limestones
? <i>Epimayaites</i> aff. <i>lemoini</i> Spath					+	
<i>Perisphinctus</i> of the <i>plicatilis</i> group					A	
cf. <i>Perisphinctus achillus</i> d'Orbigny						A
<i>Biplices</i> aff. <i>africanus</i> (Dacqué)				A		
<i>Aspidoceras</i> sp.				A		
<i>Peltoceratiodes</i> cf. <i>constantii</i> (d'Orbigny)				A		
<i>Belemnopsis tanganensis</i>				A	A	

A*—fossils listed in Report No. 22, Ayers.

W—fossils described by Weir *et. al.*

+—fossils collected during present survey.