PRELIMINARY REPORT ON THE JURASSIC SEQUENCE IN THE GEDO AND BAY REGIONS (SOUTHWESTERN SOMALIA)

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1. PREFACE

The aim of the geological research, the results of which are here contained, is the improving of the knowledge on tha stratigraphic series of Somalia. It is hope of the authors that such studies will continue in the Faculty of Geology of the Somali National University.

The region chosen for the study has many outcrops of Cretaceous and particulary of Jurassic rocks. Several facies etheropies make the local geology of a complex interpretation. Unfortunately the low elevation of the mountain ridges does not allow good observations on the thickness of the geological series. They must be appreciated over long distances and despite the low angle of dip of the layers. Only in few areas better conditions are found in this respect.

The use of the not confidential reports delivered by the oil companies to the Ministry of Mining and Water Resources in Mogadishu has been very useful for our research. They are often accompanied by detailed stratigraphic logs of the drilled wells, paleontological lists and photogeological maps of the concession areas. They have been particulary conclusive for the recognition of the thickness of the geological units.

(*) da: "Quaderni di Geologia della Somalia", Vol. V°, pag.1-26, Mogadiscio 1981.

We are particulary grateful to the Minister of the Mining and Water Resources, Dr. XUSSEN CABDULOAADIR OAASIN, to the General Director Dr. MAXAMED SAALAX XAAJI XASAN, and expecially to Dr. HILLAN CABDALLA FAARAJ, Director of the Mining and Hydrocarbon Section.

Hearthly thanks are due to the Dean of the Faculty of Geology Dr. IBRAAHIM XIRSI AADAN, who made possible the researches on the field.

2. PREVIOUS STUDIES

2a. The geological literature

The first geological studies on the Bay and Gedo of Somalia are due to G. STEFANINI for the area extended on the left side of the Juba River. He studied expecially the macrofossils (1925-1939) and the age of the rock sequences. His researches were followed by those of R. ZUFFARDI COMERCI (1939), G. D'ERASMO (1932,1960), S. VENZO (1942-1949) A.M. MACCAGNO (1947), and A. VALDUGA (1952).

For the region extended on the right side of the Juba River (formerly called Jubaland) geological and paleontological researches were carried out by J.W. GRAGORY (1896-1925), A.E.D. CURRIE (1925), L.F. SPATH (1925), and J. WEIR (1925,1929).

The listed studies led to the recognition of the occurence of Jurassic and Cretaceous rocks in the region; the determination of the boundary between the two geological periods resulted difficult to be stated and controversial. The deposition of thick beds of evaporites at the boundary itself makes it difficult the solution of this problem. Moreover, the several facies etheropies existing at various levels complicate the geological situation.

The rock formations distinguished up to then were illustrated by G. DAINELLI and G. TAVANI in the International Stratigraphic Lexicon (1956).

In the Ogaden region, now under Ethiopian rule, A. AZZAROLI and G. MERLA (1959) proposed formational names for the Jurassic sequence. In 1968 and 1970 F. BARBIERI separated on micropaleontological base the Jurassic formations of the Bay region aruond Baydhabo.

In the meanwhile much impulsion to the micropaleontological, stratigraphic and structural studies, as well as to photogeological analyses, was given by the oil companies. Detailed research was carried out in the El Wakh-Mandera basin, which extends at the two sides of the Somalia-Kenya border.

Among the several reports we must remember expecially those by M. BELTRANDI (1965) and by A. CORTESINI and G. GIANNINI (1970) for

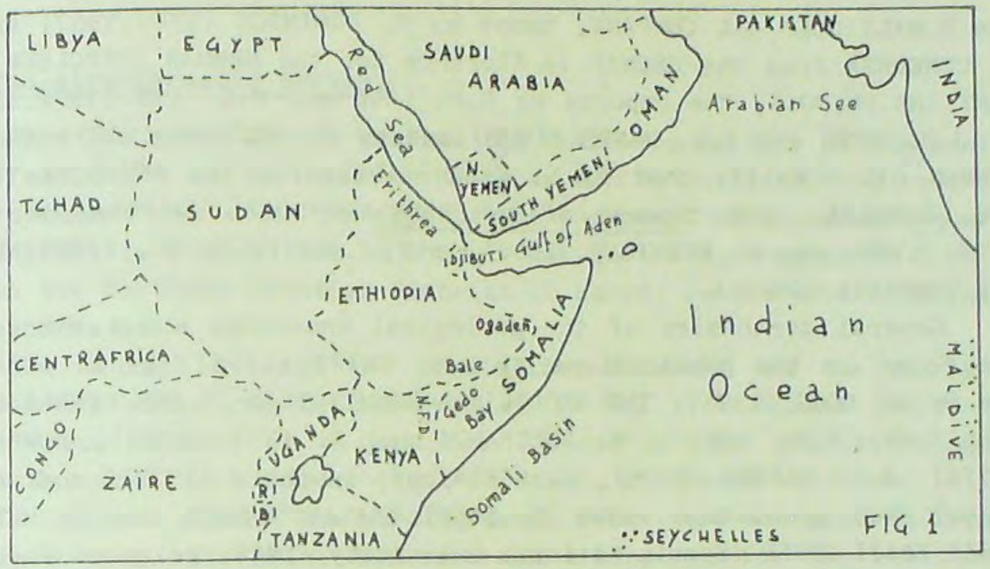


FIG 1

TECTONIC SKETCH OF THE INVESTIGATED AND NEIGHBOURING AREAS

FIG. 2

the SOMALI GULF OIL COMPANY, those by E. DOMINICO (1966,1967) and by C. COMEDERA from the GEOMAP in Florence for the HAMMAR PETROLEUM COMPANY (HA.PE.CO.), the reports by G.H. LONG and M.L. LEE (1972,1973), by J.D. HAYS and C.S. BANKS (1972) and by J. STEVENS (1973) for the BURMAN OIL SOMALIA, that by L. MARCH (1963) for the DEUTSCHE TEXACO A.G. SOMALIA, some reports of the SINCLAIR SOMAL CORPORATION (a.o. by P. LYONS and A. DENNISON, 1960), and of the CO.NO.DO. (CONTINENTAL OIL COMPANY) SOMALIA.

General synthesies of the geological knowledge about the region are found in the publications by W.O. CLIFT (1965), by A. AZZAROLI and by L. COGG (1971), THE GEOLOGICAL SURVEY TEAM OF THE PEOPLE'S REPUBLIC OF CHINA (1972), M. BELTRANDI and A. PYRE (1973), ROMPETROL (1975), S.U. BARNES (1976), G. MERLA and coauthors (1979), and in the unpublished graduation works by CABDI SAALAX XUSEEN and by MAXAMED XASAN XAAJI AXMED (Somali National University, 1978, relators F. CALVINO and HILAAL C.F.). The geographic position and the characteristics of the drilled wells for hydrocarbon research in Somalia, Ethiopia and Kenya are listed in a work by R. BIGNELL (1977).

As far as the facies etheropias are concerned, the different formational names introduced for the sedimentary rocks of Bay and Gedo regions, of Ogaden and sometimes of the subsurface must be remembered. Other names were given to the rock units in Kenya. They are illustrated in the report of the GEOLOGICAL SURVEY OF KENYA by H.G.BUSK (1939) F. DIXEY (1948), F.M. AYERS (1952), B.H. BAKER and E. P. SAGGERSON (1958), by A.O. THOMPSON and R.G. DODSON (1958,1960), by P. JOUBERT (1960,1963), by E.P. SAGGERSON and J.M. MILLER (1963). They all contain geological maps and figures at various scales.

A first proposal for a rational interpretation of the etheropies in Somalia was made by HILAL, G. PAVAN and E. ROBBA (1977); (see also G. MERLA and others, 1979). G. PICCOLI and HILAL summarized the paleontological knowledge on the Somali stratigraphic series (1978).

The first geological maps are those at 1:2.000.000 by G.STEFANINI (1932) and by G. DAINELLI (1943). Other maps are due to A.AZZAROLI and G. MERLA at 1:500.000 (1957-1959) and at 1:4.000.000 (1970), to V.N. KOZERNKO at 1:1.000.000 (unpublished, 1970-1972), and to G. MERLA and coauthors at 1:2.000.000 (1973, with illustration Notes in 1979). A photogeological map of the region between the Juba and Shebeli River at 1:1.000.000 was presented by P. CANUTI, M. FAZZUOLI and P. TACCONI at the Symposium on the geology of the Afro-Arabian rift system, held in Rome in 1979. Unpublished photogeological maps at various scales are contained in many reports of the oil companies as said before.

2b. The stratigraphic series

From the above listed studies the following picture of the geological situation in Southwestern Somalia can be outlined. The sedimentary sequence rests on the crystalline basement, of a gneissic-quartzitic-granitic composition. It crops out in the Bur region in Somalia and in the Northern Frontier District in Kenya, in the area of Moyale, Buna and Wajir.

The contact between the crystalline basement and the overlying sedimentary rocks can be observed at 17 Km. from Baidos (Baydhabo) towards Bur Hakaba, in a road cut. It can be seen also at Matagoi, at 11 Km. from Iach Bravai (Yaaq Baraawe), southwest of Dinsor (Diinsoor). In both places the stratigraphic rocks were assigned to Dogger or Upper Lias. STEFANINI had recorded a Lias age for the limestones near Matagoi, for their paleontological contents. Among the fossils Gervilleia, Megalodon, Lima punctata SOW. and Cytherea astartoides THEVENIN were found. Later on, the lowest geological age ascertained was the Callovian with Ammonites, as for instance Grossouvria anomala LOCZY.

In the region bordering on Kenya and Ethiopia, S. VENZO affirmed the existence of Bathonian rocks with Trigonia.

The situation in the underground resulted to be somewhat different. Liassic limestones containing Orbitopsella praecursor GUEMBEL, Labyrinthina compressa HOTTINGER and Vidalina martana FARINACCI were found in boreholes. This fauna is typical of the Tethyan realm and it was met in the drilled well at Garad (Garad Mare 1) by AGIP.

A lithological and stratigraphic equivalent was found in the Gheferso well, drilled by Burmah Oil Somalia (1974). Rocks of Lower Lias and Trias were met in the Brava 1 well of Sinclair. The related formation is the Adigrat Sandstone; some authors believe it to be an equivalent of the Karroo Formation of Southern Africa. The karroo Formation is made up of continental deposits, particulary sandstones, which are extended from South Africa to Mozambico, Madagascar, Tanzania, Kenya. Other searchers denay the equivalence of Karroo and Adigrat sandstones. In Northern Somalia (to Tigrai) the Adigrat Sandstone extends up to Toarcian; thin interbeds of limestone contain in fact the Ammonite Bouleiceras arabicum. G. PAVIA is studing now coeval ammonitic faunas in the Baidoa Formation, which rests on the crystalline basement in the Bur region.

In El Wakh (Coel Waaq) area a thick series of Triassic and Lower Jurassic age was decovered under the Baidoa Formation. According to

geoseismical research, its thickness was calculated to be over 4000 m. A conglomerate layer was met at the bottom of the Hol 1 drilled well. It was interpreted as an equivalent of the Mansa Guda Conglomerate (of Trias-Lias age), which crops out near Tarbaj in Kenya. It is covered in the Hol 1 well by azoic limestones and evaporitic-dolomitic layers, for over 2300 m. of thickness. On them the rocks of the Baidoa Formation follow upwards.

Severe tectonic movements in Upper Trias and Lower Jurassic are testified by this situation. A deep groove developed near the present border of Somalia and Kenya. It has been soon filled by detrital rocks and later by lime muds and evaporites. This sedimentary basin was long and narrow. It continued in the Lamu Embayment, which opened towards the Indian Ocean.

In Dogger the marine sedimentation extended all over the region. The outcrops if its rocks allow a detailed study of the geological history of the area.

The lower units belong to the Iscia Baidoa (Isha Baydhabo) Formation, which extends upwards to the Oxfordian. The bottom part is represented by conglomerates and sandstones, which are called the Deleb Member. In lateral and position the Uanei(Waneey) Member follows, formed by limestones, marls, shales and sandstones.

The Baidoa (Baydhabo) Member is formed by micritic limestones, with oölithic layers, and supports the Goloda (Golooda) Member, of crystalline limestones with stylolithes, oölithic levels and coquinas containing Bivalves and Brachiopods.

The maximum thickness in the type sections are of 50 m. for the Deleb Member, 100 m. for the Uanei, 90 m. for the Baidoa and 650 m. for the Goloda Member. It makes a total of almost 900 m. for the Iscia Baidoa Formation.

The sedimentation began in a continental and deltaic environment (Deleb Member), continued in a reducing auxinic and lagoonal environment (sediment rich in pyrite crystals) for the Uanei Member, then became marine littoral, with thin sediments, for the Baidoa Member and lastly took place in the open sea, in a neritic enviroment, with small coral colonies and algal stomatolithes (Goloda Member).

On the Baidoa Formation, the Anole (Canoole) Formation consists of 500 m. thick marls, shales and sandstones. Its outcrops are very poor. The age of it was stated as Oxfordian-Kimmeridjan, on the base of Ammonites, Belemnites, and Bivalves. Also corals were found, mostly individual. The sedimentation environment was marine, epineritic to mesoneritic. In this time the deepest conditions of the whole sequence

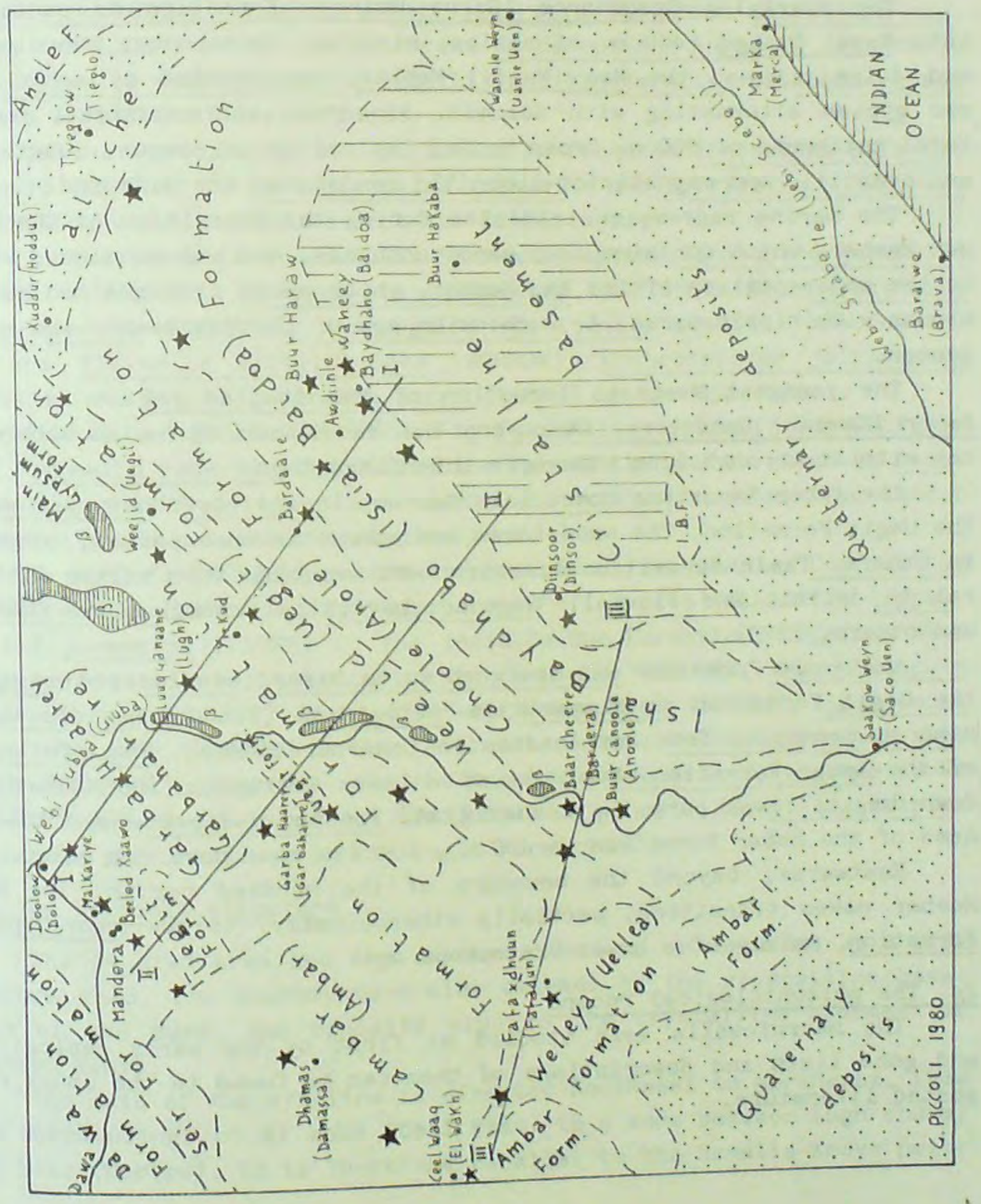
FIG. 3

SKETCH MAP OF THE INVESTIGATED AREA

Scale 1:2000000

★ Sampled series

I Section traces



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were reached.

On the Anole Formation the Uegit (Weejid) Formation lies. Its thickness is about 350 m.; the rocks are limestones of calcareo-pse phitic and calcareo-pelitic type, with oölithic beds and some pisolithic and coquina beds. Recrystallisation and dolomitization phenomema were recognized at the microscope. The depositional environment variated from mesoneritic to littoral.

The overlying Garbaharre (Garbo Haarey) Formation is partaged into Busul Member (400 m. of shales, micritic limestones, sandstones and dolomias) and the Mao (Macaw) Member, represented by anhydrite and gypsum alternating with dolomia, limestone and sandstone, for a total thickness of 300 m. Cross bedded lamination in common. Quartzose and hematitic and magnetitico-limonitic sandstones are diffused.

The marine regression initiated during the deposition of the Busul Member, which contains also sandy coquinas, and was concluded with in the sedimentation of the Mao Member, which shows fine grained sandstones with ripple-marks. A. Purbeckian age of the Mao Member was suggested.

The youngest Mesozoic formation of the studied region is the Ambar (Cambar) Sandstone. It covers the Mao Member, but also alternates with it through long etheropic interfingerings.

the Amber Sandstone comes into contact in its lowermost part with the Uegit Formation. The sandstones are porous in some partes, compact in others. Their depositional environment variated from marine littoral to deltaic and fluvial. They are partially transgressive (MERLA and others, 1979).

the Anole Formation was assigned to an Oxfordian-Kimmeridjan age, the Uegit Formation to Kimmeridjan-Portlandian (Tithonian), the Garbaharre Formation from Portlandian to Lower Cretaceous. The main part of the Ambar Formation should be of a Lower Cretaceous age, reaching down in its lower part the Kimmeridjan. The maximum preserved thickness of the Ambar Formation is 450 m., but its roof does not exist.

Eastwards, beyond the boundary of the studied region, the Mao Member makes transition, partially etheropically, to the Main Gypsum Formation, mainly of a Lower Cretaceous age.

2c. The paleontological record

The macrofossils were studied at first by the early geologists and good lists and descriptions of them can be found in the above reported literature.

As far as the microfossils are concerned, apart of the Foraminifera and Ostracoda described in the literature, some fossils recovered in the drilled wells can be recalled.

In the Middle-Upper Jurassic (Callovian, Oxfordian, Kimmeridjan) the following Foraminifera are common: Marsonella oxycona (REUSS), Epistomina parastelligera (HOFKER), Epistomina stellicostata (BIELECKA & POZARYSKI), Epistomina depressa (SAID & BARAKAT), togheter with Textularia jurassica (GUEMBEL), Guttulina pera (LJIKER), Spirillina kuebleri (MATLJUK). Among the Ostracoda Cytheropteron purum (G. SCHIMDT), Pontocyprella suprajurassica (OERTLI) and Monoceratica cf.sundancensis (SWAIN & PETERSON) are diffused.

In the Portlandian are particularly frequent Trocholina palastiniensis (HENSON) (= Kurnubia palastiniensis) and Spirillina polygyrata (GUEMBEL), which continued from the Kimmeridjan;

In the Lower Cretaceous, in Barremian-Aptian, Glomospira gordialis (JONES & PARKER), Marssonella subtrochus (BARTENSTEIN), Gevelinella cf.intermedia (BERTH.), Hedbergella washitensis (CARSEY) are common, as are Ticinella miltiloculata (MORROW), Conorotalites jaffarensis (SIGAL), and Biglobigerinella barri (BORRI) in the upper part.

The Albian faunas are marked by Planomalina buxtorfi (GANDOLFI), and Ticinella roberti (GANDOLFI); the Cenomanian and Turonian by Praeglobotruncana, Rotalipora and then Globotruncana species. The latter ones are found outside the studies zone.

In 1968 F. BARBIERI recorded from the surface samples Coprolithus cf.salevensis (PAREJAS), Cylyndroporella cf.arabica (ELLIOTT), Clypeina aff.jurassica (FAVRE) in the Iscia Baidoa Formation, together with Nerinea and Itieria; Lenticulina tricarinella (REUSS), Vaginulinopsis cf.pasquetae (BIZON), Epistomina aff.mosquensis (UHLIG), Epistomina parastelligera (HOFKER) in the Anole Formation; Pseudocyclammina jaccardi (SCHRODT), together with the Ammonites Idoceras durangense (BURCKHARDT) and Idoceras rufanum (DACQUE'), Calpionellidae, Ellipsactinia, Ostracoda and Characeae in the Uegit Formation.

2d. The tectonic structure

The studied area and the nearby zones can be regarded as a wide synform fold. Its southwestern side estends to the crystalline basement of the Burs, the opposite side to the crystalline basement of Eastern Kenya.

The axis of the syncline is directed Southwest to Northeast, from the surroundings of El Wakh (Ceel Waaq) to a zone between Lugh (Luuq) and Dolo (Doolow). It is Therefore parallel to the Somalia-Kenya poli-

tical border in its northernmost portion.

The wide fold is affected by minor ones. Axial undulations complicate the structure and so do several faults,mostly with a small throw.

The first fault to be listed should be that putting into contact the sedimentary and crystalline rocks at the northeastern border of the Bur crystalline basement. Its strike is Northeast-Southwest (Bur North Fault or Baidoa Fault).

A parallel fault is likely to exist at the southeastern border of the same Bur crystalline basement (Bur South Fault).

The biggest axial undulation is the axial swelling detected in the zone of El God drilled well; here the Ambar Sanstone reaches its biggest preserved thickness.

The minor folds converge towards this area, as for instance on the western side the El God and respectively Cursi anticlines, striking to North-North-East. On the eastern side the anticlinas of Hol and of Garbaharre and the Tomalo syncline inbetween converge as well to the same zone, striking to North-East.

The main axis of the wide syncline is called Bahallo axis ("bahallo" means "wild beasts"). The axial dipping toward the North of its southern part received the name of Domadare and Fafadun (Fafaxdhuun) arch. The dipping to the South in the northern part was indicated as Tossile transversal anticline (COMEDERA, 1970).

Another North-East swelling follows between Luuq and Doolow and corresponds to the northern side of the transversal anticline.

The main fault run parallel to the axis of the big and flat syncline. Repetition of stratigraphic units is caused in some parts, as around Garba Haarey (Garbaharre).

In the same direction are ranged the eruption centers of the Tertiary and Quaternary volcanic activity (of basaltic type). Remains of flows, with some ashes beds, extend in a wide area from Baardheere (Bardera) to Weejid (Uegit) and Luuq (Lugh) towards the Ethiopian border.

Photogeological analysis of the satellite imagery (LANDSAT) were carried out at the Somali National University by SHUKPI HILOWLE CADDAWE (1978) and by XUSSEN CABDULLE JAAMAC (1979) for their graduation research, in Baardhere and Diinsoor areas respectively.

In the first zone, where sedimentary rocks of Jurassic age are prevailing, two system of faults predominate, with a mean direction North 51° East and respectively North 37° West. The first system is often cut and displaced by the other one, with sinistral movement and an offset of 200 to 400 meters. The faults belonging to the second

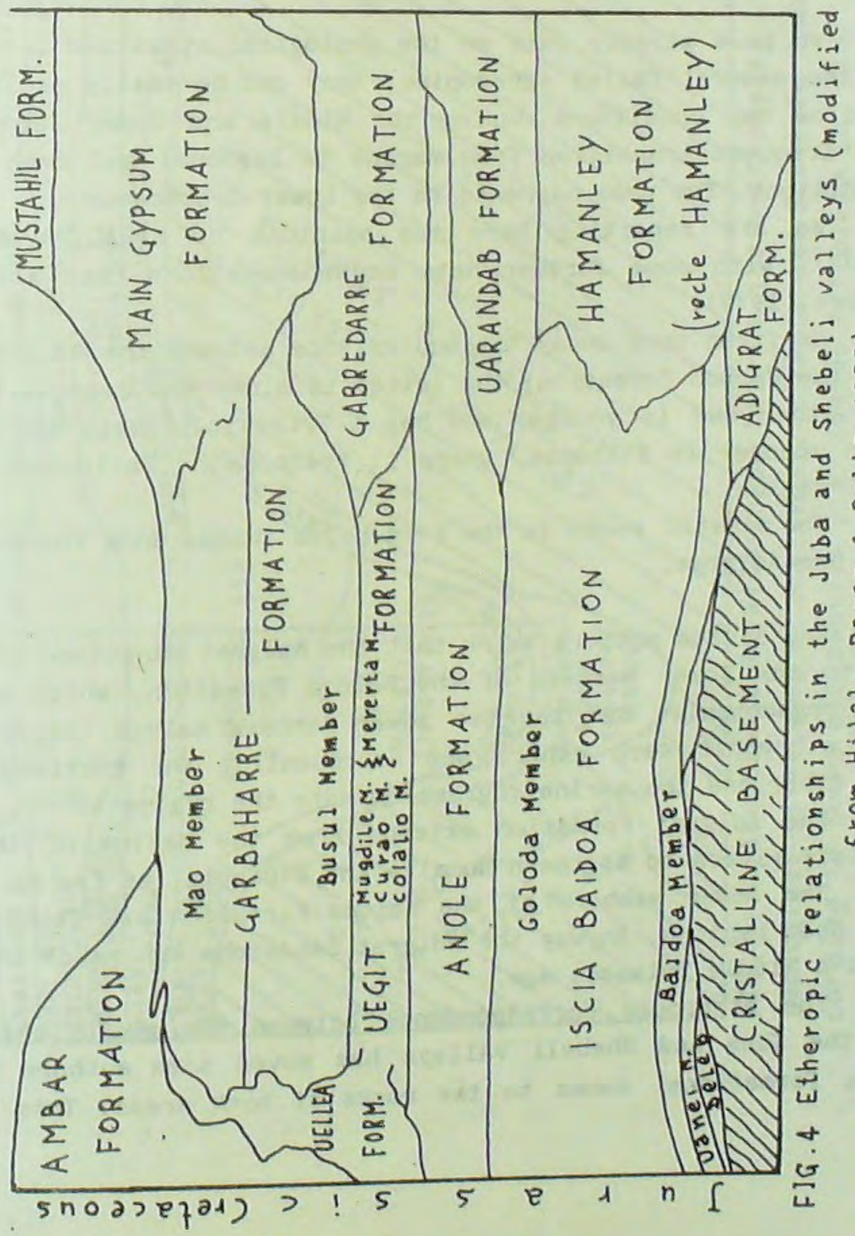


FIG.4 Etheropic relationships in the Juba and Shebeli valleys (modified from Hilal, Pavan & Robba 1977).

system are sometimes arranged radially within an angle of about 10°. North-South faults are rare.

In the second remembered area, North-East and North-West faults are prevailing. The first ones cut sometimes the other; the opposites situation is much less common. This fact is particularly spread out in the crystalline basement. The displacement is sinistral. The movement must be put into relationship with the opening of the Indian Ocean and the contemporary displacement of India, drifting toward North-North-East (SOMMAVILLA, 1977).

3. THE ETHEROPIES

We have already said as the geological situation is made complex by the several facies etheropies; they can be easily explained by the shallow sea conditions during the Middle and Upper Jurassic and by the frequent transition from marine to lagoonal and even continental conditions. The same happened in the Lower Cretaceous.

We are reporting here the opinions of HILAL, PAVAN and ROBBA (1977), with some further data and observations (see also MERLA and others, 1979).

As first they denay the equivalence between the Adigrat Sandstone and the Uarroo Formation; the letter is older and extends to the Trias the other one is younger and has a Triassic-Liassic age in Somalia, even younger in Ethiopia, where it reaches the Callovian, in the Tigrai region.

The clastic rocks in the bore holes (Mansa Guda Formation a.c.o.) are pre-Adigrat.

The listed authors think that the Adigrat Sandstone is contemporary to the lower members of the Baidoa Formation, which are detrital and organogenic. But the two lower members selves (Deleb and Uanei) are etheropic each other, one representing the continental facies, the other one the marine ingression onto the region of the Burs.

The Adigrat Formation extends from the basins of the Jube and Shebeli rivers to Northern Somalia and Ethiopia, as far as Erythrea.

The lower members of the Baidoa Formation are found in the Bay and Gedo regions. Anyway the Adigrat Sandstone can reach in its lowest part a Middle Triassic age.

The etheropic correspondence between the geological formations in the Juba and Shebeli valleys has moved some authors to give the same formational names to the rocks of both areas. This solution is

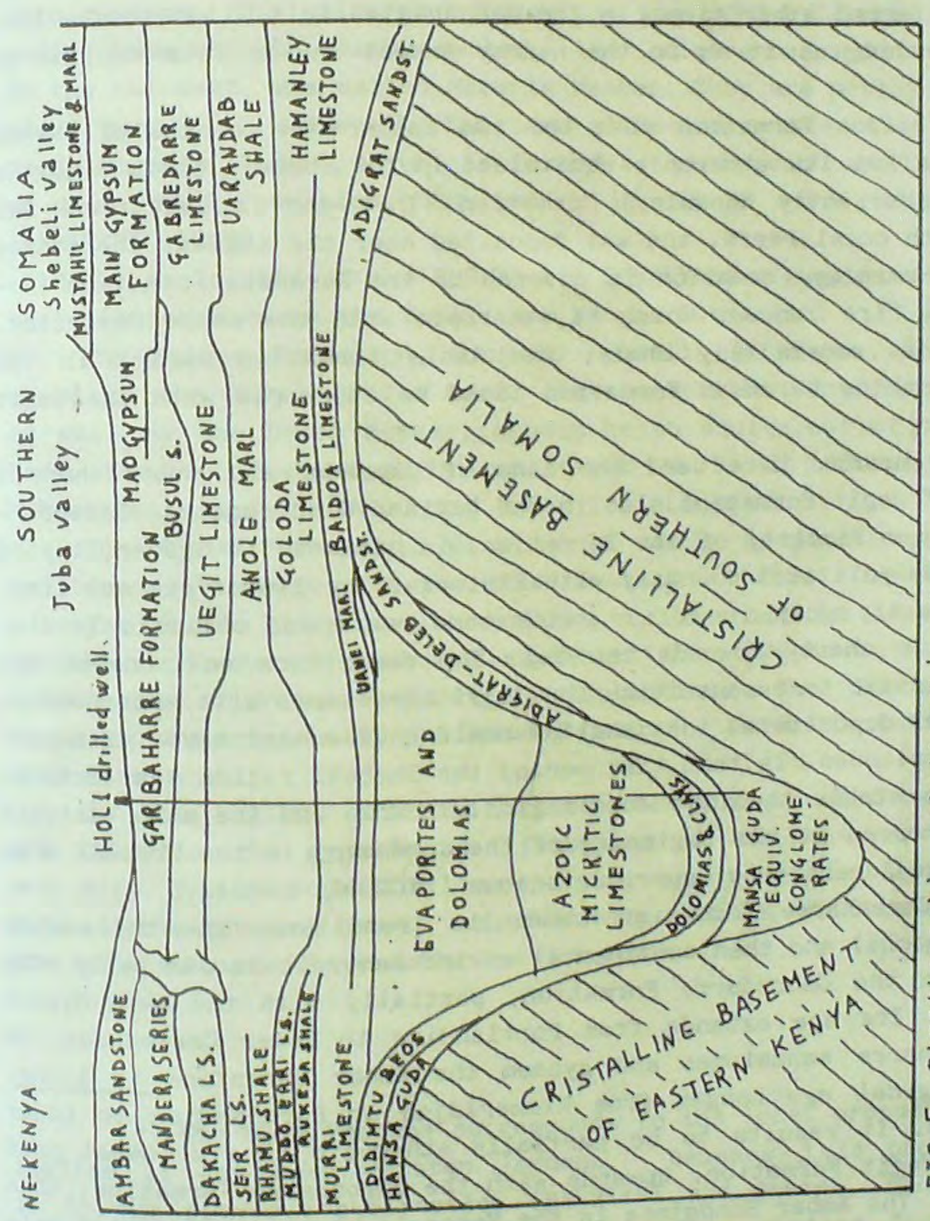


FIG.5 Stratigraphic relationships between the outeropping and buried geological formations of Northeastern Kenia and Southern Somalia (according to Burma Oil Somalia ltd. Hammar Petroleum Co. ltd. and Hilal, Pavan & Robba 1977, with new observations).

not always the best. They are indeed separate rock bodies, with pretty different lithological characters, so that they represent different formations according to the lithostratigraphic nomenclature rules. The contained faunas are sometimes different, due to various enviromental conditions.

Facies interfingerings are often very clear and allow to recognize the inferred etheropies. In the Gedo region this situation is largely extended, as it is in the nearby Bakool region (its capital is Xuddur).

The Baidoa Formation with the two calcareous members of Baidoa and Goloda has its etheropic equivalent in the Shebeli basin with the Hamanley (correctly Hananley) Formation. This one is calcareous and marly, with coral reefs, and was daposited near the ancient shore line.

The Hamanley Formation is covered by the Uarandab Formation (Waran dab = Fire lance), which is etheropic with the Anole Formation. That one is essentially shaly, the Anole Formation marly. In its upmost part the Uarandab Formation could be etheropic with the Uegit Formation.

Some authors have used the name of Gabredarre (Oabridahrre) instead of Uegit Formation also in the Bay and Gedo regions. Gabredarre, the type locality of the formation, is situaded in Ogaden, beyond the present political boundary with Ethiopia. The lithotypes are limestones, mainly grey in colour, with some reefs and oölithic levels. They become cherty towards the top. The deposition environment was from epineritic to mesoneritic. The Uegit Limestone, with some coqiune levels, was depositated in a shallow shelf environment maybe with some lagoonal episodes. In that time period the Shebeli region was tectonically less stable than the Juba region. In this one the main tectonic events occurred at the beginning of the Jurassic, in the Shebeli area in the late Jurassic to Upper Cretaceous (PICCOLI, 1979).

The Garbaharre Formation marks the transition from the marine to the lagoonal and then continental environment. It is partially etheropic with the Gabredarre Formation, partially with the main Gypsum Formation. Its age extends from Portlandian to Lower Cretaceous. On The Garbaharre sandstones and gypsum the Ambar Sandstone is lying. Its geological age ranges from Kimmeridjan or Portlandian to Lower Cretaceous. It results to be partially etheropic in its lowest part with the Uegit Formation, upwards with the Garbaharre Formation, then covers it. The Ambar Sandstone is the Mesozoic youngest formation existing in the Juba valley in Somalia. In the Shebeli basin, on the contrary, the marine sedimentation started again in Upper Cretaceous

and only towards the end of this period and iun Paleogene continental Sandstone will be deposited. They represent the Yesomma Sandstone (*).

A calcareous unit, the Uellea (Welleya) Formation, extened etheropically in the region of El Wack and Fafadur in respect of the Ambar, Anole and Uegit Formations. The Uegit Formation itself was partaged into members. The calcareous lower one was called Colalio Member, the marly intermediate Curao Member, the calcareous upper one, which is the thickest, was called Mererta Member. They are partly in succession, partly in etheropy. The same situation occures for the arenaceous Mugdile Member, which is formed by sandstones similar to those of the Ambar Formation, from which it can be hardly distinguished (BARBIERI, 1968).

The geologiste of the BURMAH OIL SOMALY have suggested the follow equivalences between the Somali and Kenyan Formation.

The Baidoa Formation, wich is overall calcareous, should correspond to the Murri (Malka Mari) Limestone; tyhe Uanei Member of it, as wall as the Deleb Member, should be an equivalent of the Didimtu Beds. The Goloda Member is considered to be in otheropy with the Rukesa Shale and the overlying Muddo Erri Limestone.

The Anole Formation, wich is of marly composition, is to be considered etheropyc with the Rhamu Shale and the Seir Limestone.

The Uegit Limestone corresponds to the Dakacha Limestone; the Garbaharre Formation has its equivalent in the Mandera Series, of arenaceous-calcareous-evaporitic composition. The Mandera Series is partly etheropic with the Ambar Sandstone, as the Garbaharre Formation does.

In the region, extended around the borders of Somalia, Kenya and Ethiopia the gypsiferous lithotypes of the Garbaharre, Mandera and Main Gypsum Formation are joining and can't be distinguished. But at the present time, unfortunately, it is difficult to visit the areas situated beyond the Somal border.

(*) The name Yesomma corresponds to the local pronunciation. In Italian it has been written Jesomma, because j is pronuncied as i. In our previous publication (BARBIERI and Others, 1979) we have erroneously used the spelling Gesomma. This writing form must be abandoned, as Prof. G. Merla has kindly suggested to us.

4. NEW GEOLOGICAL OBSERVATIONS

4a. The marine transgression and the stratigraphic series of Lias

The beginning of the marine transgression onto the peneplanized region formed by the crystalline schists in Southern Somalia has been assigned by various authors to different epochs.

The Adigrat Formation was ascribed in doubtful form to Upper Trias or Lower Jurassic, more on the base of analogy with other parts of Africa than for true paleontological reasons. It is formed by lacustrine and palustrine deposits of continental origin and does not represent the record of the advancing sea onto the dry land. Detrital deposits of this type have been reporter in the studied region in a zone Northeast of Dinsor.

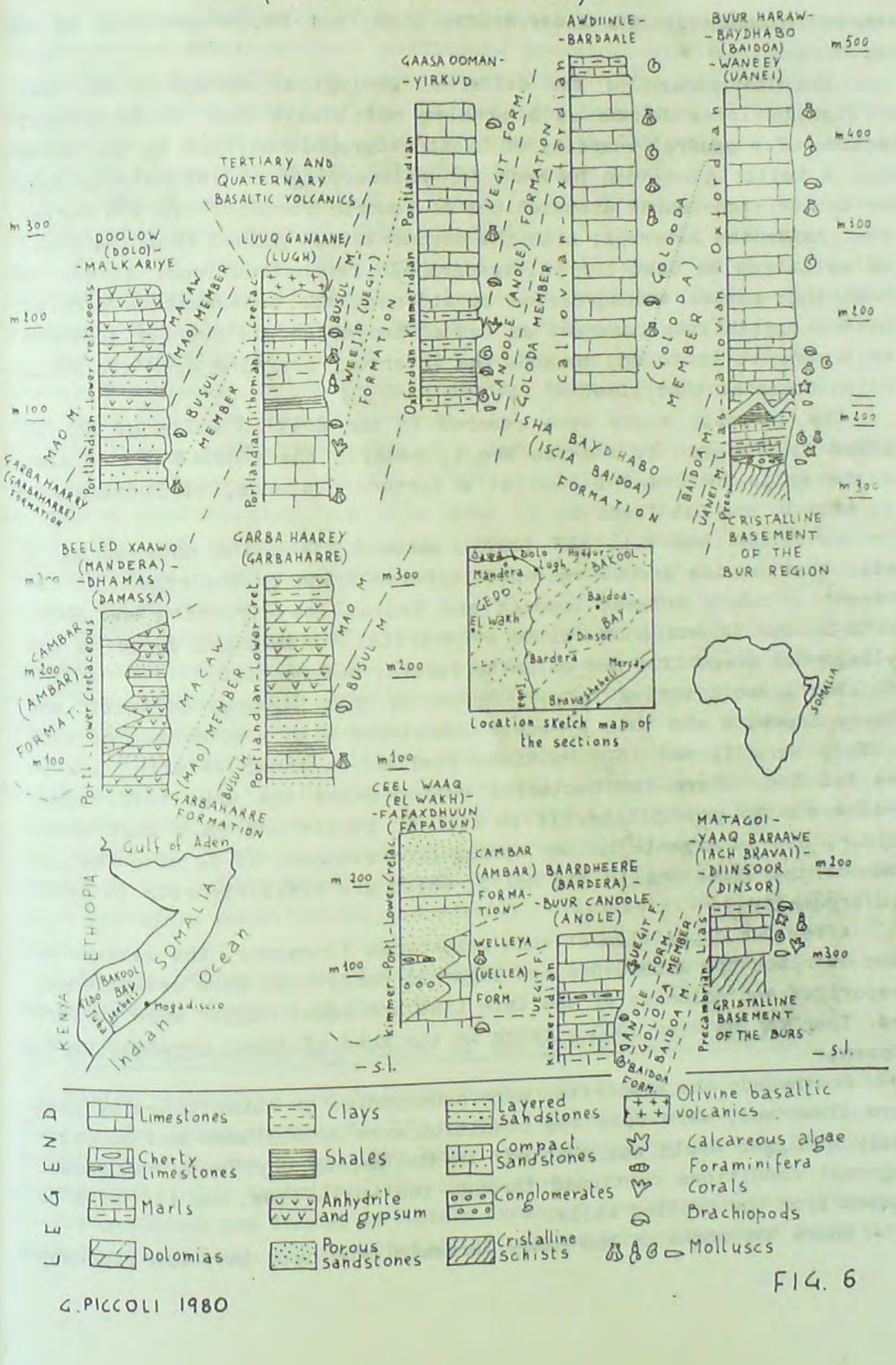
In the SINCLAIR Brava 1 drillmed wall K. MADLER of the DEUTSCHE ERDOEL-AKTIENGESELLSCHAFT (in F. PLUMHOFF's umpublished report,1977) gives a Middle Triassic age (Keuper) to sandstones and marls found 3500 and 4050 m below the country level. They contain-spores and pollens, as Chordasporites, Striatites, Cyclosaccus, Alisporites, Cayto-nipollenites, trilete forms as Verrucosisporites and monolete forms as Chasmasporites and Aratrisporites. The overlyng Liassic sediments are represented by marine limestone with fragmental Gasteropods, Hystrichospahaeridae and Dinoflagellatae, then by limnic clays with Callialasporote, Classopollis and Bonnettitales pollens. The boundary between Lias and Dogger was detetcted at about 3050 m of depth.

The new sampling made during our studies has allowed to confirm a Liassic age for the becinning of the marine trasgression in the region of Bay, around Baydhabo (Baidoa). This age had already been suggested by G. STEFANINI in the area of Matagoi through the analysis of the macrofossile, as it has been said in the introductory pages.

A. CALDUCCI (personal comunication and publication in print on the microfacies of Somalia) has found Vidalina martana FARINACCI in the basal limestone near Baidoa. This Foraminifera has been recorder from the offshorn AGIP Garad Mara 1 drillad well between 3700 and 3800 m of depth, in a limestone lying on the Adigrat Formation. Now it has been found in outcrops.

The marine ingression had been already assigned to Upper Lias, Toarciano, on the base of Labyrinthina mirabilis WEINSCHENK and Cylyn-droporella arabica ELLIOT and to Domerian with Orbitopsella praecur-ded Cylyndroporella cf. arabica, Clypeina aff. jurassica FAVRE, Copro-litus (Favreina) cg. salevensis PAREJAS and other microfossils. The new founds makes it possible to suppose that the marine ingression

STRATIGRAPHIC SECTIONS OF THE GEDO AND BAY REGIONS
(SOUTH-WESTERN SOMALIA)



G. PICCOLI 1980

FIG. 6

started already in the Lower-Middle Lias, not better precised up to now.

The distinction of the different geological epochs on the base of fossil flores faunas is a problem not always easy to be solved, because of a general scarsity of biostratigraphic markers in the Jurassic. A better study can be made for paleoecological reconstructions, due to the rich faunal associations of benthic Foraminifera and Ostracoda. Aside the outcrops, alto the documentation gained from the drilled wells can be used for paleogeographic reconstructions. It can be shown that marine transgression is older on the southwestern side of the Bur crystalline basement as far as Kenya, and is younger toxwards the North, it is to say towards the interior, starting from the young Indian Ocean at that time.

The Jurassic rocks wers reached in the drilled wells of Hol 1, El God 1, Gheferso 1, and Das Wen 1; outside the studied region also in the wells of Brava 1 and, at a further distance, of Duddumai 1, Bio Addo 1, and Gal Tardo 1.

G.H. LONG and M.L. LEE (1973) assumed, from the data of Hol 1 well, that a wide groove was open in Permo-Trias in the region at the present boundary between Somalia and Kenya. Its direction was about North-South. It was soon filled by detrital continental deposits and by lagoonal evaporitic and solomite layers, before Lias.

The Liassic series is represented by thin lagoonal dolomitic and clayey deposits and then by azoic limestones with a trickness of 1300 m. They were formed in conditions similar to those existing now in the Red Sea, where the bacterial action below tha wave level makes a lime mud to precipitate. It is rich in pyrite and ha a dark brown colour, due to organic matter coming from without. It is also the colour of the limestone in the Hol 1, which are similarly rich in pyritic crystals.

After the deposition of such gray-brown limestone, the sedimentation overcame the subsidence and lagoonal conditions were established. Evaporites and dolomias of the late Lias and basal Dogger were so formed. They can be over 1000 m thick in the zone of their greatest development.

Southwards the evaporites were accompanied or substituted by platform limestone, were open sea condition were established and occasionally a bigger depth was reached. In the neerby dry land, in Ogaden, lagoonal conditions continued through the whole Lias, as it could be stated from the drilled walls.

Where the rocks of the Early Jurassic crop out, they are represented by clastic sediments of continental and transitional environment. Conglomerates and quartzose sandstones deriving from the erosion of the underlying crystalline basement were formed. The related formational name is Deleb Member of the Iscia Baidoa Formation. It can be confused from a lithological point of view with the Adigrat Formation and is an equivalent of it, formed in the same time.

On the Deleb Member shales, marls and thin calcareous layers represent the Uanei Member, which is partially etheropic with the other one. Rocks of such a level crop out in small areas of a wich belt, extending from the surrounding of Baidoa to Saco Uen (Saskow Weyn).The exposures are generally poor. The Deleb and Uanel rocks flank laterally the evaporitic layers of late Liassic age, found in the drilled wells. The Uanei layers contain marine fossile (Ammonites e.o.) in some beds and are a coastal deposit.

On then micritic limestone of a dark gray-brown colour represent the Baidoa Member. At the fresh cut the colour is dark, but on the weathered surface they are pale grey to white. They are layered in thin beds and thick layers with a thin inner lamination; also some oolithic levels occurre. Residual clay separates the layers in case of weathered rock.

The overlying part of the Baidoa Member is formed by coerse bioclastic limestone, with Brachiopods and lesser Gastropods and Bivalves. The coquina levels testify conditions of high energy of the water during the deposition, but for the greatest part of thetime span a marine calm environment allowed the deposition of a fine lime mud, which gave origin to micritic lithographic limestone. Recrystallization phenomena were observed in thin sections. On paleontological base the age was stated to range from Domerian to Callovian. Therefore the Baidoa Member extende in time from Lias to lower Malm,as it is proved by macrofossils, expecially molluscs, studied by STEFANINI.

At the beginning of Middle Jurassic the Bur region of Somalia was completely covered by the sea.

4b. The marine sedimentary series of the Middle-Upper Jurassic

Marine conditions are found everywhere in Dogger in Southern Somalia. In the Aalenian several Trocholina in reef facies are present,as B. PRESTAT has described. The beds with Trocholina rest on Toarcian layers containing Ammonites (now under study).

The flores and faunas of Middle Jurassic are know in the region both from outcrops and bore holes. In Ogaden microfaunas of Bajociar

age were recovered from drilled wells.

In an area of Somalia and Southern Ethiopia S. VENZO studied molluscs of Batholian age. In the Baidoa Limestone benthic Foraminifera, particularly Valvulinidae, were found as well as calcareous algae (Uragiella).

If the marine fossils of the Uanei Member were correctly determined, the age of the member is partially the Middle Jurassic. It results therefore at least partially etheropic with the Baidoa Member. The observations were made over long distances. On the other side no important change in the thickness of the Baidoa Member could be Stated.

The sedimentary series of the Middle Jurassic is altogether thin and correspondes to the general marine ingression in the studied region. Circalittoral (or mesoneritic) conditions were reached. High energy conditions can be found rather far away, in Kenya, in the Middle Jurassic rocks of the Mandera District.

The Murri (Marka Mari) Limestone contains bioclastic levals and coquina with Bivalves. It represents the lower part the Dawa Limestone and attains 600 m of thickness, according to the reports of the Geological Survey of Kenya.

If Lias was a period of severe tectonic movements in Southern Somalia, the Middle Jurassic (Dogger) was on the contrary a period of prevailing stability. The maximum thickness of sedimentation occurred in the Upper Jurassici and it took place in a shallow sea.

The Goloda Member of the Baidoa Formation overlies conformally the Baidoa Member; its age ranges from Callovian to Oxfordian. The commonest rocks are calcirudites and calcarenites with oolitic levels, bioclastic layers and calcareous coquinas. These rocks crop often well out in the Bay, Bakool and Hiiraan regions.

The tracks on this formation's rocks are generally bad, because of the cobbles and pebbles covering the ground or the rock diffused everywhere. Karstic and paleocarstic phenomena are common, particularly around Xuddur and Tiyaglow.

Calcareous algae and coral colonies were found in the upper part of the Goloda Member. In the coquinas Brachiopods are the most abundant fossils, followed by Bivalves and then Gastropods. Fine grained limestone are more frequent in the Goloda Member in the area around Dinsor and Bardera in respect of that around Baidoa and Uegit, where coarse grained limestones are more common. It means that the southwestern area was further from the coast and sedimentation took place below the wave level. The marina ingression had arrived far in the Oga

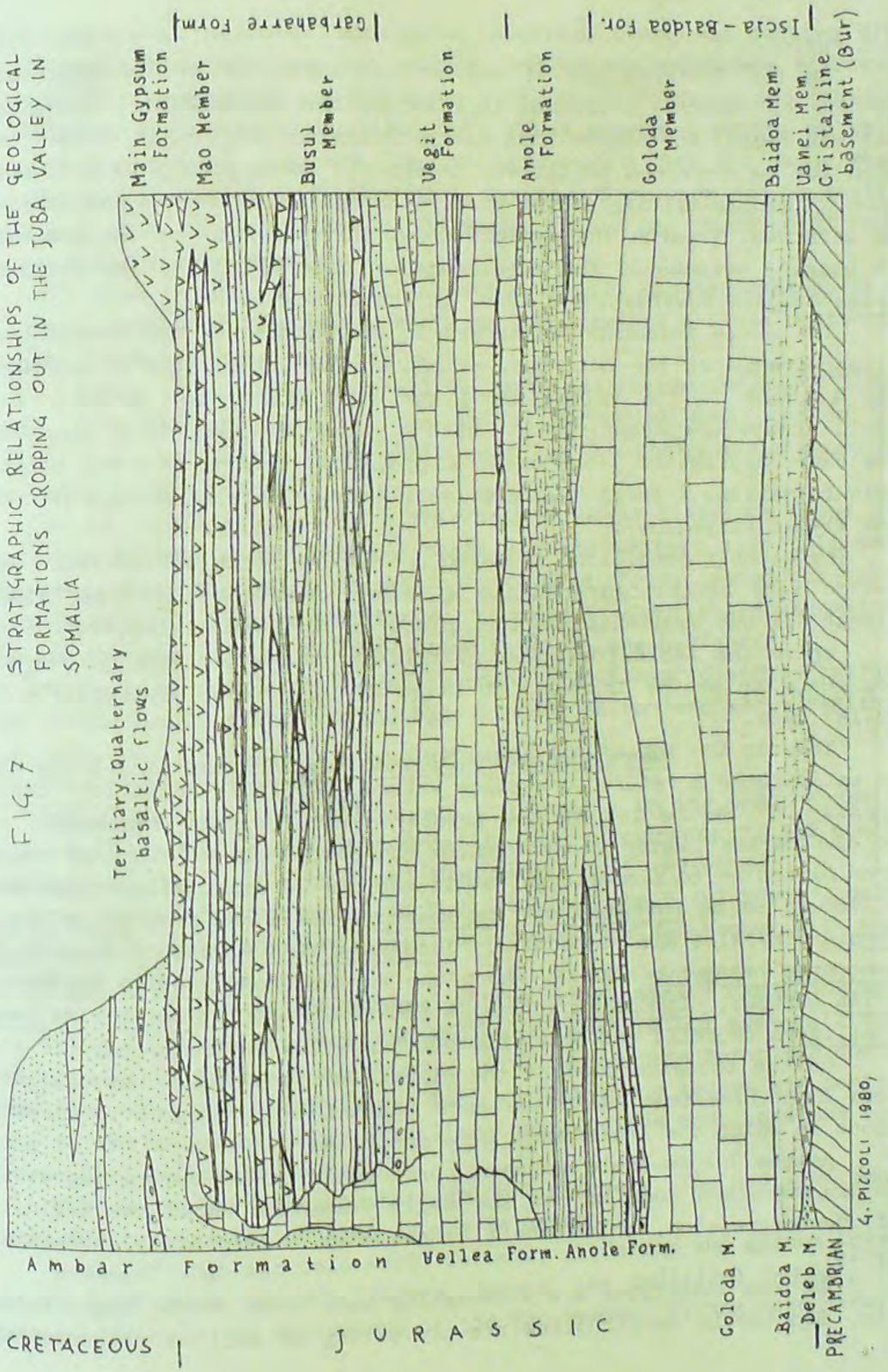


FIG. 7

den region.

In the Gheferso and El God drilled wells, at the northern side of the Bur Uplift, a gradual increase of thickness of the Goloda Member was found. Northwards high energy limestone are known. This situation can be referred to tectonic movements contemporary to sedimentation. A gentle tilting of the zone, with uplifting of the sea side,can be inferred. Towards the ancient coast the thickness of the sediments is bigger, because of the subsidence of this side. The thickness decreases again towards the inland, in the Hol well.

The Anole Formation is marked in the country by the almost total disappearence of the outcrops, except in few areas. Good observations can be done in the valley along the Juba River near Bardera. Here marls clays are cropping out, with silstone and sandstone levels and few dark bioclastic limestones. A grey-pink soil covers the area of this formation. A large "caliche" belt extende between Hoddur (Xuddur) and Tieglo (Tiyeglow).

The deposit conditions in which the marine rocks of the Anole Formation were sedimented indicate a deeper sea then in former times. Almost all the sedimentation took place below the wave levet.

Where the Anole Formation is thicker, the underlying Goloda Member seems to become thinner, at least as it can be inferred from the wells' data.

Towards the top of the Anole Marl some biolastic level with coquina anticipates a return to shallow waters. The Anole Formatio corresponds to the period of the greatermarina Jurassic ingreasion and to the deepest water conditions in the studies area. Its age ranges from Oxfordian to Kimmeridian, as it was stated expecially on the base of Ammonites as Euaspidoceras perarmatum (SOW.) and Procerites anolelensis STEFANINI and respectively Idoceras rufenum (DACQUE') and Paracenoceras hexagonum (SOW.). Among the Foraminifera Lenticulina tricanella (REUSS), Glomospira gordialis (JONES & PARKER), Epistomina parastelligera (HOFKER) and other benthonic species are recorded.

On the opposite side of the El Wakh-Mandera basin the fossiliferous Seir Limestone testifies more coastal conditions in respect to those in which the Anole marls were deposited.

As the Goloda-Anole sequence corresponds to the marine ingression in Southwestern Somalia, so the Uegit Formation shows the beginning of the regression, which shall close later the Jurassic sedimentary cycle.

Various lithotypes are alternating each other in the Uegit Formatio. Bioclastic calcirudites are prevailing as well as calcarenites.

Intraformational breccias containing micritic limestone pebbles are found. Oolitic levels are not seldon, whilst the marls are scarsely represented, expecially in the upper part. Coral colonies and individual corals (genus Montlivualtia) were found near the bottom as well as near the top of sequence. In the upper part they are associated with calcareous algae and pisolithic layers. Some beds can be easily conffused with those of the Goloda Member. Also the trachiconditions are similar or even worse.

The area in wich the Uegit Formation is well exposed extends from the surroundings of Bardera to the type locality and follows eastwards towards the Uebi Shebeli valley.

The basin of Bardera dam shall be contained inside the Uegit limestone. Also the shoulders of the dam at Markablei shall lay on the Uegit rocks, while the base shall rest on the Anole marls and Juba alluvion.

Due to tectonic reasons, a thir belt of Uegit limestone crops out East Garbaharre, whers a NE-SW fault has its western side uplifter. Another area of the Uegit Formation containing cherty limestones extends between Beeled Xaawo and Bhamas (Damassa), where tho northeastern side of the big Lugh-El Wakh syncline comes to the surface.

The age of the Uegit Formation spans from Kimmeridjan to Portlandian (Tithonian), stated on the base of both macro- and microfossils.

4c. The end of the Jurassic marine sedimentary cycle

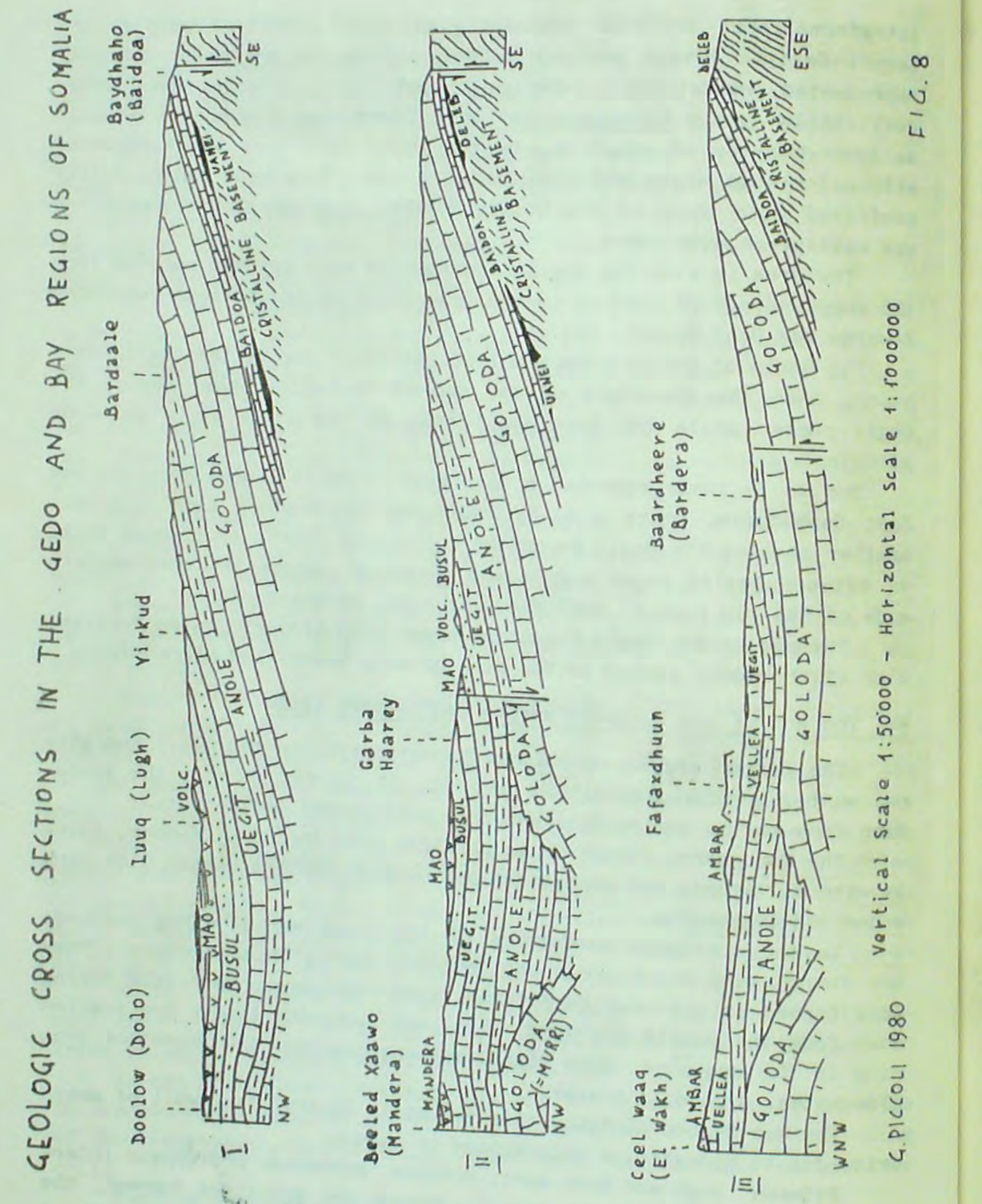
The Garbaharre Formation rests conformally on the Uegit Formation, with a gradual transition from it. It corresponds to the evolution from marine to lagoonal and then continental enviroment.

The Garbaharre Formation is partaged into the Busul Member, mainly with siltstones and sandstones and upwards the Mao Member with sannstones ad evaporites.

In the quartzose sandstones of the Busul Member sandy coquinas are found, with Brachiopoda and Molluscs (among which oysters). They were formed in littoral conditions, with terrigenous materials coming down from the nearly dry land Marl and limestone lenses are scattering in the sequence, also with limestone coquinas and limestone conglomerates. Gypsum is scarse.

The Mao Member contains thin dolomitic layers. The swall of anhydrite due to hydratation into gypsum is common.

Between Lugh and Dolo marl, dolomia, sandstone and gypsum intercalate each other in thin layers. Beyond the political border, the Mandera Series in an equivalent of the Mao Member. It has been refer -



red to Upper Jurassic.

The sedimentation environment of the Garbaharre Formation corresponds to the end of the Jurassic marine sedimentary cycle. In its lover part it results of a Portalndian age, in its upper part of a Lower Cretaceous age.

On the Mai Member of the Garbaharre Formation the Ambar Sandstone rests. The sandstones are marine in their lower part and then continental. In its lower part the Amba Formation stays by the Mao Gypsum, then it covers the gypsum. The rock is a quartzose-micaceous sandstone with magnetic and hematitico-limonitic levels, of a black-brown and dark red colour.

Long interfingerings with the Mao gypsum are found. Cross lamination of the deltaic and fluvial environment can be easily seen around Mandera and El Wakh. In some basal level thin Pectinidae shells are recorded.

In its lowermost part the Ambar Sandstone stays side by side with the Uegit Limestone, with unconformable relationship.

A long calcareous tongue extende from Fafadun towards El Wakh. It supports the sandstone, but is also partially etheropic with them. The 'imestone is white micritic, with calcarenitic levels, layered in thick beds. It makes transition to the Uegit Limestone. Earlier ascribed to this formation, it was later named Uellea (Welleya) Formation. In its lowermost part it is etheropic with the Anole Marl, near Saco Uen.

The age of transition from marine to continental deposits is different in the various parte of the studied area, as far as it cam be judged from the stratigraphic relationsships between the formations. It cam range from Upper Jurassic to Lower Cretaceous. It is earlier northwards, while in the southern part the Uellea limestone continued to be deposited.

Basal regressive conglomerates of the Ambar Sandstone, recorded in the literature, were not found by us. Conglomeratic levels can be seen in all the lower part of the sandstone sequence, as well as thin levers of cherty limestones.

The thickness of the Cretaceous sandstones should have been originally bigger than now. It reaches its greatest value (about 450 m) in the center of the El Wakh-Mandera syncline.

Outside the mone, on the rocky formations a thin cover of Recent surface deposits extende. It covers southwards a Tertiary continental deposit, known from drilled wells.

Of a Tertiary and Quaternary age are also olivine basaltic flows

and tuffs, extending in the Juba valley North of Bardera and widening northwards, beyond the political border of Somalia.

5. CONCLUSION

The stratigraphic series in the Bay and Gedo regions of Southwestern Somalia and in the nearly parts of Kenya and Ethiopia corresponds to a complete marine sedimentary cycle, from the beginning to the erd of the Jurassic period.

Continental deposits of a Cretaceous and ther Tertiary age and few volcanics of a Tertiary-Quaternary age follow.

The marine ingression began in Lias in a deep groove extending near the present border of Somalia and Kenya.

Later on, the transgression extended all over Southern Somalia, reaching as far as the regions of Bale and Ogaden in the Middle Jurassic.

With the Upper Jurassic the regression towards the present day coast of the Indian Ocean took place.

The sedimentary sequence indicates sea conditions from littoral to mesoneritic, at the moment of maximum deepening with a later return to coastal sedimentation and then to legoonal and terrestriam environment.

The dry land was always situated at the Nortwest.

The thickness of the stratigraphic series variate from place to place, reaching a maximum total value of 2500 meters of marine and transition sediments. The variations of thickness indicate tectonic movements contemporary to sedimentation. Under the outcropping stratigraphic seriae 4000 meters of terrestrial and coastal sediments were detected underground and partially reached in drilled wells. They are of a Triassic and Liassic age and are confined to the groove mentioned above.

The present tectonic structure can be out outlined as a wide and flat syncline extending between the crystalline basement of the Bur region in Somalia and that of the Northern Frontier District in Kenya. The axis of the fold oriented NE-SW.

A subject for future research could be the equivalences between the Jurassic sequence in the Juba valley and in the Shebeli valley, Ogaden included. The sedimentary environment was partially different, due to the tectonic history of the area.

The studied sequence represent the oldest part of the Somali stratigraphic series in the southern parte of the country.

ESTIMATED CONDITIONS OF SEDIMENTATION IN THE CENTRAL PART OF THE STUDIED AREA

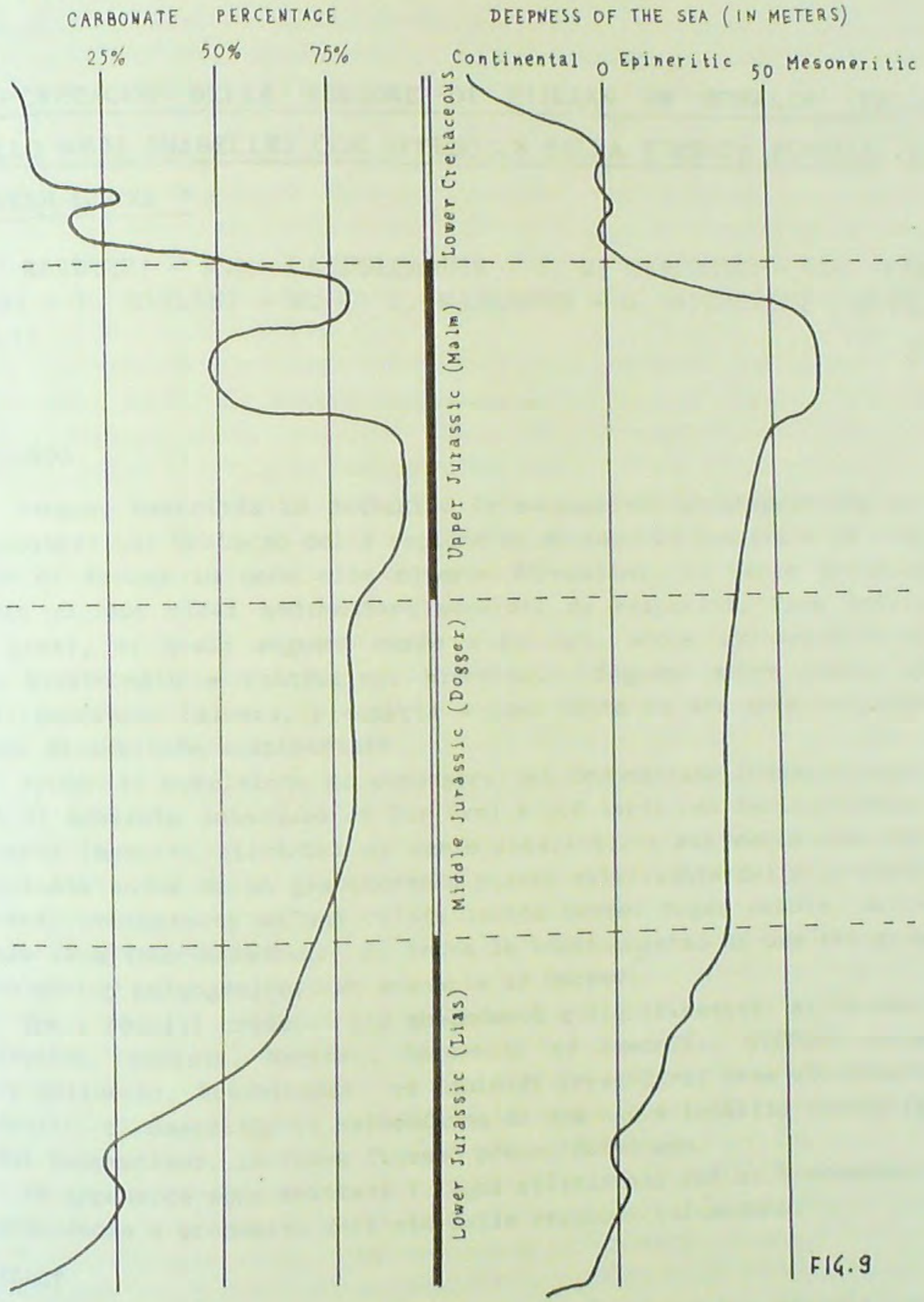


FIG. 9