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Permian Reef Complex, Tunisia

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ABSTRACT.—The only exposures of marine Permian strata in northern Africa form an inlier in southern Tunisia. The outcrops, some 18 square kilometers in extent, exhibit a sequence of at least 850 meters of marine strata grading upward into nonmarine redbeds. Apparently conformable relationships of Permian and Triassic strata and the gradual regressive sedimentation of the Permian section suggest a quiet withdrawal of the Tethyan sea not interrupted by plate collision.

The Permian rocks represent a reef complex between a shale basin to the north and shelf sediments on the Saharan Shield margin to the south. Two large bioherms in the western area interfinger eastward with drab shale and are overlain by a thick Permo-Triassic redbed section. A large bioherm at the eastern end of the range grades westward and upward into drab shale and shelf carbonates.

Reef frame is indeterminate in the ordinary exposures of the major bioherms, whereas scores of well-preserved small bioherms display zoned frames of tabulate corallines, bryozoans, sponges, and algae. General lack of reef talus and presence of micritic reef matrix suggest a low-energy environment. Interbioherm faunas contain abundant sponges, bryozoans, and tabulate corallines. Brachiopods, gastropods, bivalves, and various echinoderm groups are quantitatively insignificant. A fine sequence of fusulinaceans of the *Neoschwagerina-Yabeina* assemblage makes this section ideal for a regional Permian stratotype.

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INTRODUCTION

Well-exposed and remarkably fossiliferous marine Permian rocks of southern Tunisia at the western tip of the Tethyan seaway have been known and frequently cited for more than forty years, but neither the fossils nor the stratigraphy have been well evaluated. It is the purpose of our present work to contribute to the understanding of the Permian biostratigraphy of the fossils. These surely constitute one of the world's great Permian assemblages. The present work is preliminary to laboratory studies of the fossils by many taxonomic experts.

The Tunisian Permian outcrops are limited to a small range of hills of some eighteen square kilometers known as the Medenine Djebel Tebaga, and the neighboring Oum el Afia (Text-figs. 1 and 2). They are overlapped unconformably by nearly flat-lying Jurassic and Cretaceous rocks (Plate 2, fig. 4). Comparable Permian exposures are unknown elsewhere in northern Africa, and the nearest outcrops of marine Permian rocks are in the Sosio Valley of Sicily. These famed Sicilian Permian rocks are exceedingly fossiliferous olistoliths of limestone, lacking any stratigraphic framework. We anticipate that the Tunisian Permian will provide valuable information for reinterpreting the Sicilian Permian faunas.

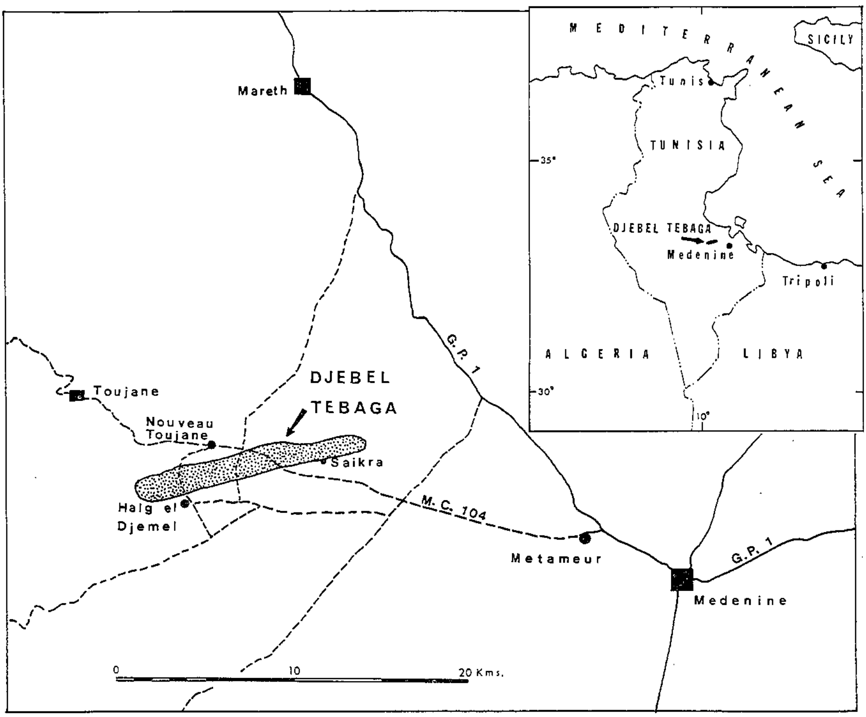
The tropical Tethyan embayment of the great late Paleozoic world ocean had gradually retreated eastward from Morocco after early Carboniferous time, and from Tunisia after Capitanian time, leaving Africa, southwestern Europe, and the Americas dry and firmly sutured together in the supercontinent Pangaea.

Tethyan sequences of Permian-Triassic rocks in the southern Alps and farther east in Eurasia all show concordant or paraconformable transitions that suggest possible continuous occupancy of the sea there until late in Middle Triassic times. It is now clear that this was a time of general crustal calm.

The stratigraphic evidence at the Paleozoic-Mesozoic boundary in all the relatively complete sequences indicates that there was no marked deformation anywhere in the Tethyan region between the early Carboniferous and mid-Triassic. The special episode of latest Paleozoic mass extinction of marine invertebrates that started earlier in the Permian was accelerating toward the end of the Permian period. Evidently it was conspicuously out of phase with any important plate movements now recognized. Perhaps a thorough analysis of our zonally collected fossils may add significant information about the patterns of Permian extinctions.

Location

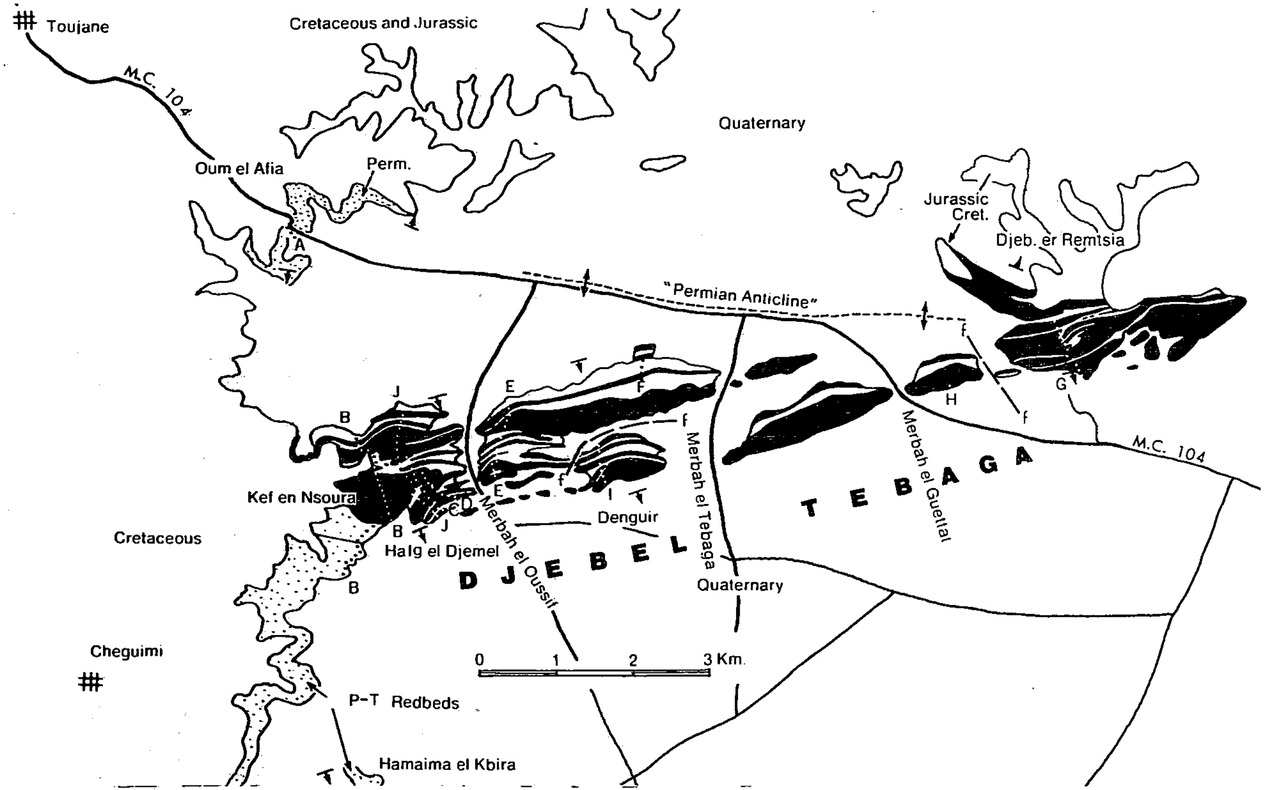
The Djebel Tebaga region (Text-fig. 1) lies approximately 25 kilometers northwest of the town of Medenine, along the base of the escarpment of the



TEXT-FIGURE 1.—Index map of Tunisia showing position of the Djebel Tebaga Permian outcrops near Medenine, in the southern part of the country.

Dahar Plateau. Permian rocks crop out in northeasterly trending hogbacks from approximately 33° 22' N and 10° 11' E to 33° 27' N and 10° 18' E. The hills occur along the boundary between the "states" of Medenine and of Gabes, and are west of the main north-south highway along the shore region. The Berber community of Toujane is along the Medenine-Matmata road approximately 10 kilometers northwest of the Permian outcrops and the community of Matmata is approximately 30 kilometers northwest. Medenine, our base of operations, is approximately 440 kilometers south of Tunis. The small villages of Nouveau Toujane, approximately 2 kilometers north of Djebel Tebaga, and Halg el Djemel, approximately 5 kilometers to the southwest of Djebel Tebaga (Text-fig. 2), are local centers of population concentration and provide limited sources of supplies and groceries. Nouveau Toujane is on the main road between Medenine and Matmata.

Several gravel and dirt roads provide access to the hogbacks of the Djebel Tebaga region (Text-fig. 2). A moderately high-speed road, Highway MC 104, leads northwestward from the village of Metameur, near Medenine, through the Permian outcrop belt, to Nouveau Toujane, Toujane, and Matmata (Text-fig. 1). This maintained dirt road connects with paved roads at both Matmata and Metameur. From the Toujane road numerous tracks and dirt roads branch off to serve most parts of the outcrop belt, including the villages



TEXT-FIGURE 2.—Reconnaissance facies map of the Permian rocks exposed in the Djebel Tebaga area, northwest of Medenine. Black areas are carbonates and white areas in the Permian exposure belt are siltstone and shale. Dotted lines from letters A through J mark traverses of measured sections included in Appendix 1. The Saikra Biohermal Complex forms the southern series of outcrops from Denguir (section I) eastward to Djebel Saikra (section G). The Upper and Lower Biohermal Complexes are exposed in the western part of the belt from near section B eastward to sections E and F. Both the latter sections were measured, at least in part, on the long ridge of Baten beni Zid. f, fault.

of Halg el Djemel and Saikra. Automobile roads transect the hogback belt through Merbah el Oussif and Merbah el Tebaga, and connect the Toujane road with those that serve the Halg el Djemel region to the south and southwest. Most of the roads are dirt or loose gravel weathered from the alluvial fan deposits they traverse, and are passable during all but the heaviest rains. Some major drainage crossings have been prepared with concrete slabs but most are of lithified gravel or loose sand and gravel.

Medenine is connected with northern Tunisia by Highway GP 1. Metameur is west of GP 1 approximately 1 kilometer and is connected to the main highway by a paved asphalt road.

Field Work

In 1967, Francis G. Stehli of Case-Western Reserve University and Richard Grant of the U.S. National Museum of Natural History spent several days at Djebel Tebaga in preliminary studies financed by an NSF grant. Their work was facilitated by the Service Geologique de Tunisie and the Mediterranean Sorting Center of the Smithsonian Institution. Their fossils were given preliminary examination by Stevens (1975), Stehli, Furnish and Glenister, and Rigby.

In 1971, Dr. William H. Kanes, Director of the International Geologic Studies Program, University of South Carolina, invited Newell and Stehli to pursue the work already begun on the Permian of northwestern Africa. Systematic field mapping and stratigraphic studies were undertaken in January of 1974 by Newell and Stehli, and again in January, 1975, by a team consisting of Newell, Rigby, Boyd, and Driggs, leading to the reconnaissance conclusions described here.

After the collections have been given the attention of taxonomic experts duplicate specimens will be returned to the Service Géologique de Tunisie in Tunis. The 1974 collections have been accessioned as USNM number 309317 and the 1975 collections as 315212.

The stratigraphic sections described herein contain citations to field markers painted on outcrops by Professor and Mrs. Henry Faul of the University of Pennsylvania, who undertook independent fossil collecting at Djebel Tebaga in 1973 and 1974. We can now correlate many of their collecting localities with ours. Rigby expects to extend the field investigations at Djebel Tebaga in the future.

Stratigraphic sections were measured where substantial parts of the total exposed thickness of Permian rocks could be studied, from southwest of the village of Halg el Djemel on the west to northeast of the village of Saikra, on the east (Text-fig. 2). Sections were measured with a jacob staff, and notes were recorded in a notebook or with a magnetic tape recorder. Fossils were collected along the section traverses and from beds correlated to those of the traverses.

Three small bioherms were sampled in detail. These provide a basis for comparison with the more easily collected and sometimes more prolific shale faunas. The three bioherms are the subject of a graduate thesis by Allan Driggs, to be published later.

Fossils were sorted into biologic groups, wrapped in paper, and bagged for shipment to the various authorities working as part of the team. Large bags of collections were delivered to the Smithsonian Sorting Center at Khereddine near Tunis for subsequent shipment to the U.S. National Museum in Washington, D.C., and transshipment to the various team members.

Most of the stratigraphic sections, sections A through I, were measured by Newell. Stehli assisted him in measuring section A and the lower part of section B, and Boyd assisted him in measuring sections G, H, and I. Boyd and Rigby measured section J and the upper third of section B.

Rigby prepared a reconnaissance lithofacies map of carbonate and shale distribution and established correlations between the various sections which are far enough apart that individual key beds could not be recognized. The map was prepared on an enlarged topographic base with a scale of approximately 1:10,000.

The Hotel Agip, in Medenine, served as base of operations for both the 1974 and 1975 field seasons. Although hotels in Matmata were initially tried in 1974 the arduous trip over slow, poorly maintained mountain roads necessitated moving to Medenine. We commuted to the field each day in two Renault Fourgonnetti.

Acknowledgments

We were supported in the field by an NSF grant, GF 32510 X comprising a special foreign currency grant from the Office of International Programs, and a separate NSF dollar grant from the Earth Science section of the Division of Environmental Sciences (both grants were to the University of South Carolina), and we received additional financial support from The American Museum of Natural History, Brigham Young University, and Case-Western Reserve University.

Dr. William Kanes, Mr. Ron Bifani, Mr. David Martin, Miss Judy Riker, Miss Sallie Foster, and others with the University of South Carolina were most helpful. We acknowledge with gratitude the encouragement and aid of M. Ahmed Azzouz, Chef de la Direction de la Géologie and M. Azzedine Azzouz, Director de l'Agence Tunisienne de Public-Relations. The latter, who was an official agent of the University of South Carolina Geology Project in Tunisia, was in particular generous and hospitable far beyond the ordinary requirements of his responsibility. M. Ernani Menez of the Smithsonian Mediterranean Marine Sorting Center at Khereddine, Tunisia, shipped our collections to the United States for us.

We were ably assisted in 1974 and 1975 by Gillian W. Newell (Mrs. Norman D. Newell) with logistics and interpreting, and during the 1974 season M. Haddad Mohamed, a local resident of Ksar Djedid Halg Djemel, assisted us. We found the villagers, herdsmen, and farmers of the area friendly and helpful.

Fossils collected for systematic studies have been distributed to the following workers:

Fusulinaceans and other foraminifera: Raymond C. Douglass, U.S. Geological Survey, Washington, D.C.
Porifera: J. Keith Rigby, Brigham Young University
Corals: Helmut W. Flugel, Universitat Graz, Austria
Byrozoans: June R. P. Ross, Western Washington State College
Brachiopods: Francis G. Stehli, Case-Western Reserve University, and Richard Grant, U.S. National Museum of Natural History

Bivalves: Norman D. Newell, The American Museum of Natural History, and Donald W. Boyd, University of Wyoming
Gastropods: Roger L. Batten, The American Museum of Natural History
Cephalopods: William M. Furnish and Brian F. Glenister, University of Iowa
Blastoids and cystoids: Donald B. Macurda, Jr., University of Michigan
Crinoids: N. Gary Lane, Indiana University
Echinoids: Porter M. Kier, U.S. National Museum of Natural History
Conodonts: Walter Sweet, Ohio State University
Algae: John L. Wray, Marathon Oil Company, Littleton, Colorado

Previous Work

Since the discovery of Permian rocks in the Medenine Djebel Tebaga region in 1932 by Berkaloff (Douvillé, Solignac, and Berkaloff, 1933), the occurrence has been cited repeatedly but details of stratigraphy and facies relationships have not been well documented. Additional information on the exposures was provided by Douvillé and Valette (Solignac and Berkaloff, 1934), but it wasn't until after World War II that the rocks were examined in much detail. Mathieu (1949) and Ciry (1948) provided most of the information currently available on the stratigraphy and structure of the Permian exposure belt, in addition to providing information on fusulinacean occurrences.

Additional discussions of various fossil groups have been given by Douville (1934), Valette (1934), Ciry and Mathieu (1947), Ciry (1953), Termier and Termier (1955a, 1955b, 1957a, 1957b, 1958, 1959, 1973, 1974a, 1974b, 1975a, 1975b), Emberger (1958), Glintzboeckel and Rabaté (1964), and Skinner and Wilde (1967). Most of these studies have been without benefit of a comprehensive stratigraphic framework.

Summaries of the regional geology and geologic relationships by Baird (1967) place the southern Tunisia Permian outcrops in a regional frame, but the most detailed description to date is still that of Mathieu (1949), who has provided the basic stratigraphic and structural framework used by subsequent workers.

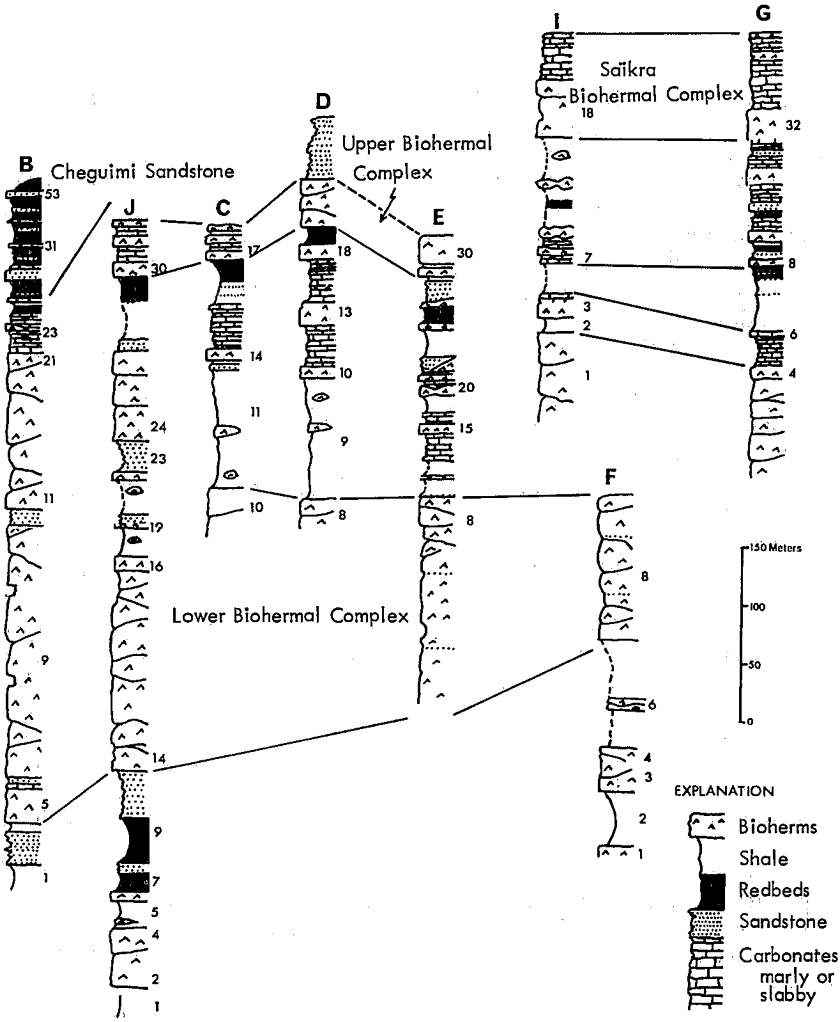
Mathieu (1949) divided the Permian rocks of the Djebel Tebaga region into six units, interpreting them from oldest to youngest: Oum el Afia Shale, Baten beni Zid Sandstone, Middle Limestone, Upper Tebaga Dolomite, Bellerophon Limestone, and Cheguimi Sandstone. He briefly described the units, but didn't report specific thicknesses for them. This is not surprising, for there are considerable facies changes and much variation in thickness. Most workers have followed Mathieu's basic stratigraphic framework, but apparently have had difficulty applying the nomenclature in detail because of abrupt facies changes and faults.

Structural and stratigraphic relationships of the Oum el Afia fossiliferous exposures (Text-fig. 2) to those of the main Permian outcrop belt are uncertain. Fusulinaceans of the genus *Yabeina* at Oum el Afia indicate possible equivalency to younger rather than older beds of the Djebel Tebaga, as believed earlier.

Because of the difficulty in relating the Oum el Afia beds to those in the Kef en Nsoura escarpment we concentrated our efforts in the more nearly continuously exposed and, to all appearances, the structurally less complicated, rocks to the south and southeast.

STRATIGRAPHY

As compared with American Permian reef complexes the Djebel Tebaga rocks are notable for the limited variety of rock types (Text-fig. 3; Appendix 1). There is nearly a complete lack of secondary silica. We did not observe any silicified fossils or nodules of chert. Most bioherms, both small and large, lack marginal fans of coarse talus or scattered detrital pebbles of limestone. Oolitic and pisolitic textures are very subordinate even in the oncolitic beds (Plate 2, fig. 1). Crossbedding is lacking in the limestones and is uncommon



TEXT-FIGURE 3.—Correlations of measured stratigraphic sections of Permian rocks in the Djebel Tebaga area. Locations of each of the sections is shown in Text-figure 2 and descriptions of the sections are included in Appendix 1.

below the redbeds, and dark colors suggestive of euxinic conditions are lacking throughout the section.

Permian strata comprising the Djebel Tebaga inlier were deposited on the hinge line between the stable Saharan Shield to the south and a deep basin to the north. Baird (1967, p. 85) notes that this unique belt of exposures is some distance south of the Atlas Mountains, in the more stable African foreland to the southeast. Permian rocks thin toward the south, west, and southeast (Glintzboeckel and Rabaté, 1964; Baird, 1967, p. 96; Bishop, 1975, p. 425) and become more evaporitic and more detrital.

The marine Permian exposures in the Djebel Tebaga area occur above a thick sequence of gray green marine Permian shale (Glintzboeckel and Rabaté, 1964; Baird, 1967, p. 94; Bishop, 1975, p. 425), and represent filling of a Permian basin by terrigenous debris, carbonates, and finally redbeds. Large fusulinaceans (*Neoschwagerina* and *Yabeina*) occur at intervals through much of the sequence and the ammonoid *Waagenoceras* is reported both low and high. The age of most of the nonred part of the section clearly is Guadalupian. Douglass tells us (pers. comm. 1975) that he favors Wordian and Capitanian. Furnish and Glenister prefer Wordian, but additional work may change those assignments.

Oum el Afia Shale

Mathieu (1949) used this name for red shale containing thin beds of limestone and sandstone that crop out in the Oum el Afia area along the Medenine-Toujane road at the base of the escarpment of the Dahar Plateau (Text-fig. 2). These softer rocks are not connected by continuous outcrop to those of the main Djebel Tebaga hogback region. The presence of *Yabeina* in the Oum el Afia strata suggests that these rocks are younger than those of Baten beni Zid to the south, in contrast to the opposite age implication of Mathieu's structural interpretation.

Glintzboeckel and Rabaté (1964) report that more than 6,000 meters of deposits of Permian age were encountered beneath 100 meters of Triassic redbeds when drilling a deep well about 4 km west of Djebel Tebaga. There is uncertainty about this, however, because the well has also been reported informally to have drilled a little over 3,900 meters of Permian beds (Baird, 1967).

Outcrops of the silty shales at Oum el Afia are predominantly greenish gray and brown, with minor limestone and sandstone units in the upper part. Limestone beds are lenticular and include both biohermal and bioclastic deposits. Bioherms are commonly recrystallized and dolomitized and are mottled tan to yellowgray. Biohermal units are massive and poorly bedded and show the organic frame only as ghosts and poorly preserved molds, sometimes outlined by ironstained films.

The softer beds generally are poorly exposed except at artificial excavations and recently eroded banks. Wherever visible the shale includes thin beds of sandstone and carbonate. The entire shale section weathers to dark or light gray green or brownish chips, with more calcareous and silty plates littering the outcrop surfaces. Some reddish shale and siltstone occur in the upper part of the exposure.

The Djebel Tebaga Reef Complexes

The strata of Djebel Tebaga, as contrasted with Oum el Afia, form a homocline with beds dipping at about 20° to 30° to the south-southeast. The strike ridges are formed by local bioherms, thin carbonate beds, and rusty sandstones (Text-figs. 4-6). The swales are cut in greenish gray to buff, brittle shales, thin bioclastic limestones, and rusty brown sandstone (Text-figs. 4-6). Outcrops are interrupted frequently by alluvial flats. Because of many abrupt and complex facies changes and more or less obscure faults, the tracing of stratigraphic contacts and the correlations of minor units are difficult.

Topographically the area is dominated by two great biohermal facies which form hogbacks along the north and south margins (Text-figs. 4, 6). The ridges generally are 75 to 125 meters high, and are separated by a central valley of less resistant, shaly beds.

At the eastern and western ends of the Djebel Tebaga range the shaly beds are replaced or dominated by a great increase in the proportion of carbonate rocks, caused by a local thickening of biohermal masses throughout the whole sequence (Plate 1, fig. 1). Wherever the carbonates are more than a few meters thick they are built of stacked, dolomitized minor bioherms interspersed with infrequent local lenses of fine to medium grained, reddish brown quartz sandstone.

Lower Biohermal Complex.—One of the major biohermal complexes, 100 to 200 meters thick, forms the crest and dip slope of Baten beni Zid (Text-fig. 4). This is a prominent ridge that forms the northern edge of the Djebel. The dolomite is the upper part of a rock division known to Mathieu (1949) as the Baten beni Zid sandstone. To others it has been the "lower dolomite." We shall call it the Lower Biohermal Complex (Text-fig. 3). The complex is mappable from the base of the Dahar escarpment west of the northern entrance to Merbah el Oussif, eastward along the hogback called Baten beni Zid to a few hundred meters beyond the Merbah el Tebaga road. Between Merbah el Oussif and Merbah el Tebaga the main biohermal part of the complex forms the resistant shoulder about halfway up the north face, caps the hogback, and controls the dip slope on the south.

EXPLANATION OF PLATE 1

PHOTOMICROGRAPHS AND FIELD VIEWS OF BIOHERMAL ROCKS OF THE DJEBEL TEBAGA AREA

FIG. 1.—Well-exposed bioherms in the middle part of the Saikra Complex (Driggs Bioherm 1) as seen looking east from section G.

FIG. 2.—Photomicrograph of fusulinacean coquina from well-bedded units a short distance below Bioherm 1 of Driggs, near the eastern end of the mound, in the Saikra Biohermal Complex. x 10.

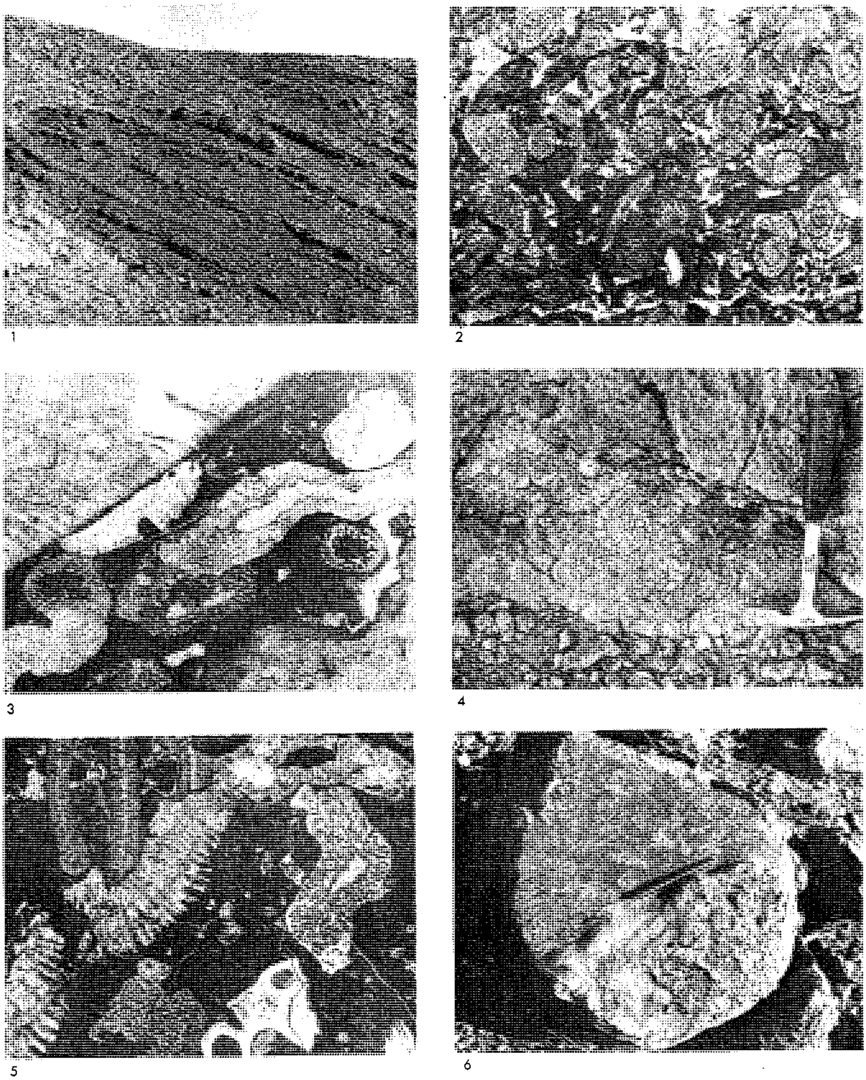
FIG. 3.—Photomicrograph of algal and sponge association which makes up much of the various studied bioherms in the Permian section in Djebel Tebaga. Sample is from the middle part of Driggs Bioherm 2, in the lower part of Upper Bioherm Complex of section B. x 10.

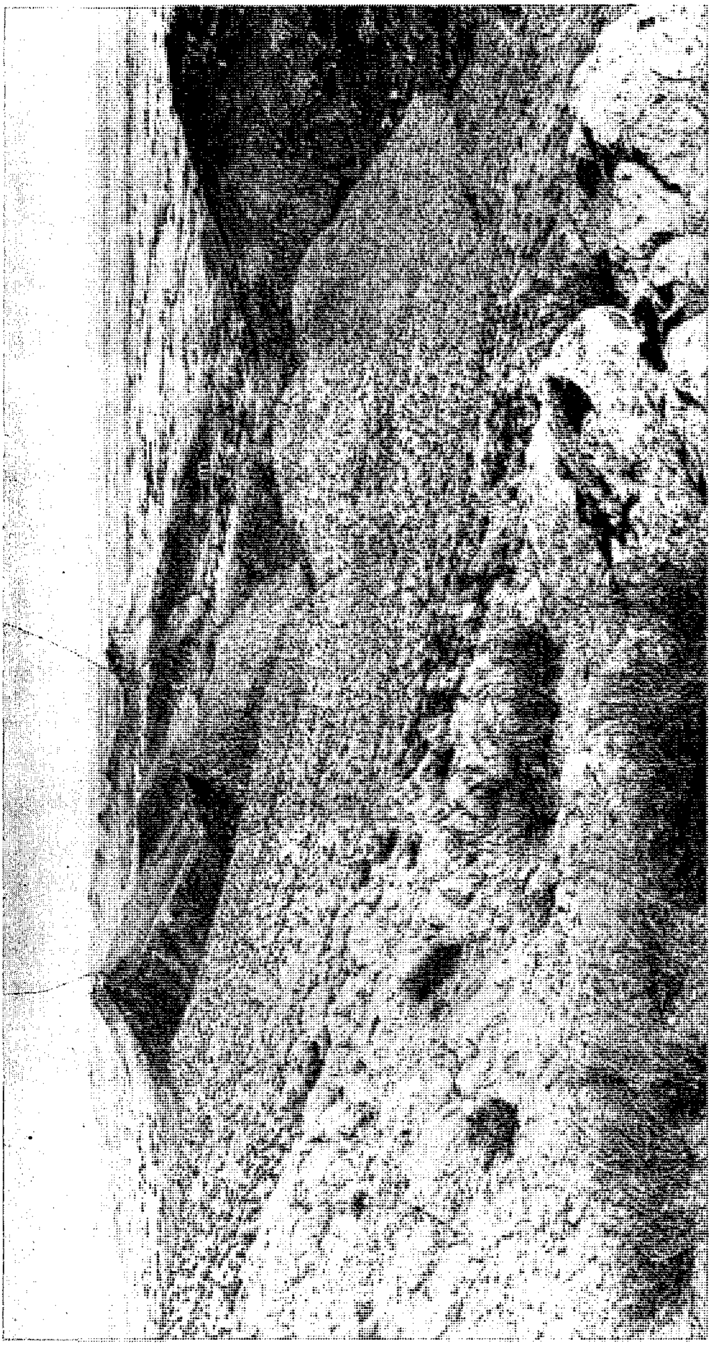
FIG. 4.—Phylloid algae exposed on the top of Driggs Bioherm 1 in the Saikra Biohermal Complex, east of section G.

FIG. 5.—Photomicrograph of phylloid algae-sponges-tabulate coral, and bryozoan (?) facies of Bioherm 1 in the Saikra Biohermal Complex. x 10.

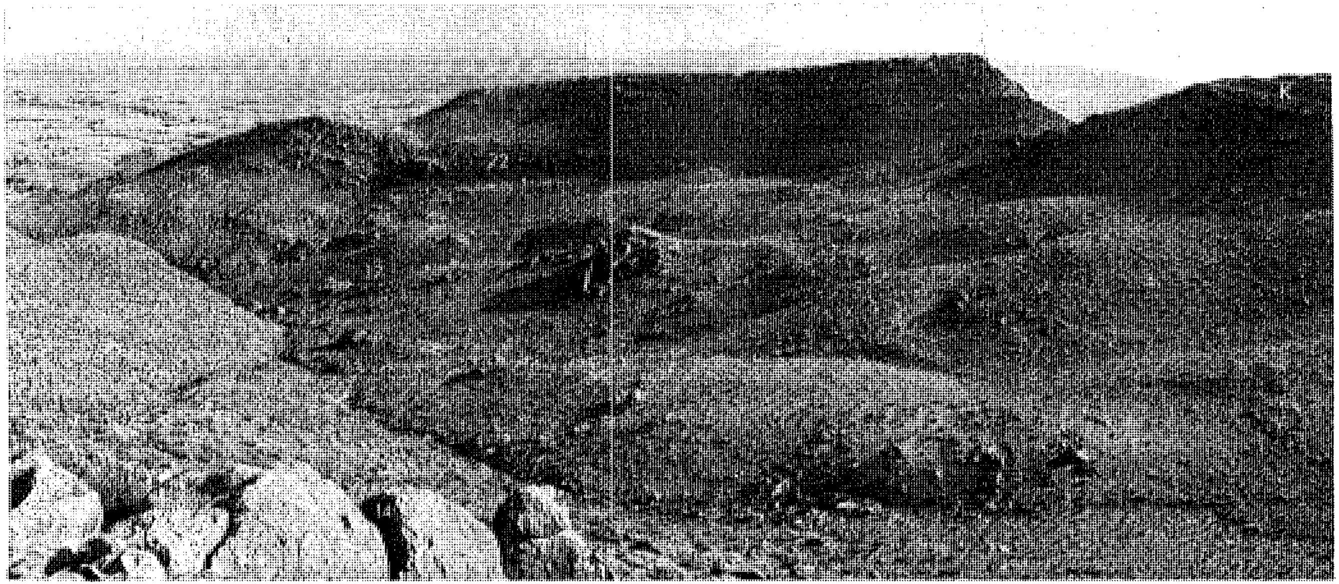
FIG. 6.—Intergrowth of sponges and tabulate corals in a micritic matrix which is typical of most of the smaller bioherms. Lower part of Bioherm 1 of Driggs, in the Biohermal Complex.

PLATE 1





TEXT-FIGURE 4.—View eastward along the Permian exposures from near the base of Kef en Nsoura, section J. Resistant carbonate units in the foreground and along Baten beni Zid (z) are part of the Lower Biohermal Complex. Those that form the low outer cuesta beyond Merbah el Oussif (m) from Denguir (d) to Djebel Saikra are of the Saikra Biohermal Complex.



TEXT-FIGURE 5.—View southward from the traverse of section J. Numbers are of lithologic units in Section J. Cretaceous rocks (K) rest with marked angularity upon the upper part of the Permian section. The Upper Biohermal Complex forms the prominent exposures above unit 22. Text-figure 5 is a continuation, toward the right, of Text-figure 4.

TEXT-FIGURE 6.—View westward along the Permian exposure belt from near section G. Units in section G are shown in white numbers. Halg el Djemel, h; Denguir, d; Baten beni Zid, z. Cretaceous rocks cap the escarpment in the distance.

The lower part of the Lower Biohermal Complex contains abundant interbedded sandstone. This part of the section is well exposed along the northern escarpment of the hogback belt west of Merbah el Oussif, in the vicinity of sections B and J, and east of Merbah el Oussif along the lower and middle slopes of Baten beni Zid. The sandstone-dominated section is approximately 84 meters thick in the section J traverse (Text-fig. 3; Appendix) including beds 8 through 13, and is estimated at slightly less than that in the Baten beni Zid exposures near the western end of the ridge.

The sandstone is ferruginous and coarse to medium grained with some interbedded sandy limestone, dolomite, and shale. Some of the interbedded carbonate units are biohermal, massive to weakly bedded, tan to brownish gray dolomite, in which fossils are preserved only as ghosts. These biohermal lenses often terminate abruptly laterally, with fine and medium sandstone lapping onto their flanks or abutting against steep terminations.

Sandstone units are usually ledge formers and commonly have a limonitic brown weathered surface. Quartz overgrowths give some units a sparkling crystalline appearance in the sun. Most sandstone beds show prominent cut-and-fill structures and contain rip-up clasts of siltstone, laminated claystone, or platy sandy dolomite. Coarse sandstone beds evidence stronger than normal currents in the basin.

Interbedded shale is usually lenticular, although not to the degree of either the biohermal carbonates or the coarsest sandstone beds. Shale is brownish red gray to light or medium olive green and is usually sandy.

In western exposures of the main part of the biohermal complex the rocks are recrystallized, light gray to medium tan-gray dolomite and weather a medium to light brownish gray. The division in western and central exposures is resistant and forms steep ledges and moderate cliffs. Some of the complex is even bedded, but most of the section in the Merbah el Oussif area is massive and appears composed of complexly stacked lenses and pods up to hundreds of meters across and tens of meters thick. Some of the lenses are outlined by slightly argillaceous limestone and dolomite or by sandy shale, and in some areas by lenses and stringers of brown-weathering ferruginous sandstone, like that in the underlying dominantly sandstone unit. Such sandstone is particularly common in the uppermost and lowermost 10 to 20 meters of the complex.

The part of the complex exposed on Baten beni Zid is apparently equivalent only to the lower part of a vertically more extensive carbonate sequence exposed immediately below the unconformably overlying Cretaceous rocks in hills at the base of the Dahar Plateau, west of Merbah el Oussif. In canyons west of section J, massive dolomite extends from the base of the complex up through rocks laterally equivalent to much of the Middle Shaly Facies, for a thickness of approximately 370 meters.

The lower part of the complex, where the rocks are shaly, shows some moderately complex small-scale folds which might be fault drag structures, particularly in the small hills near the base of section F. Permian rocks of Baten beni Zid and equivalent rocks west of Merbah el Oussif may be fault isolated from the section drilled to the north and reported by Glintzboeckel and Rabaté (1964), particularly since they report Triassic rocks structurally lower than the projected level of the Baten beni Zid Permian exposures.

Middle Shaly Facies.—The Middle Shaly Facies is an interbedded shale, siltstone, carbonate, and sandstone section which occurs south of the Baten beni

Zid part of the lower biohermal complex and north of Denguir. These shaly beds are laterally equivalent to the middle part of the thick carbonate complex exposed at the base of the Dahar Plateau north of the western houses in Halg el Djemel (Text-figs. 2, 3). The shaly beds are generally less resistant than the dominantly carbonate units above and below and in consequence form the lowlands between the two long carbonate-capped hogbacks which define the Permian exposure belt of the Djebel Tebaga region. The shaly section is well exposed, however, on ridges immediately east and west of Merbah el Oussif.

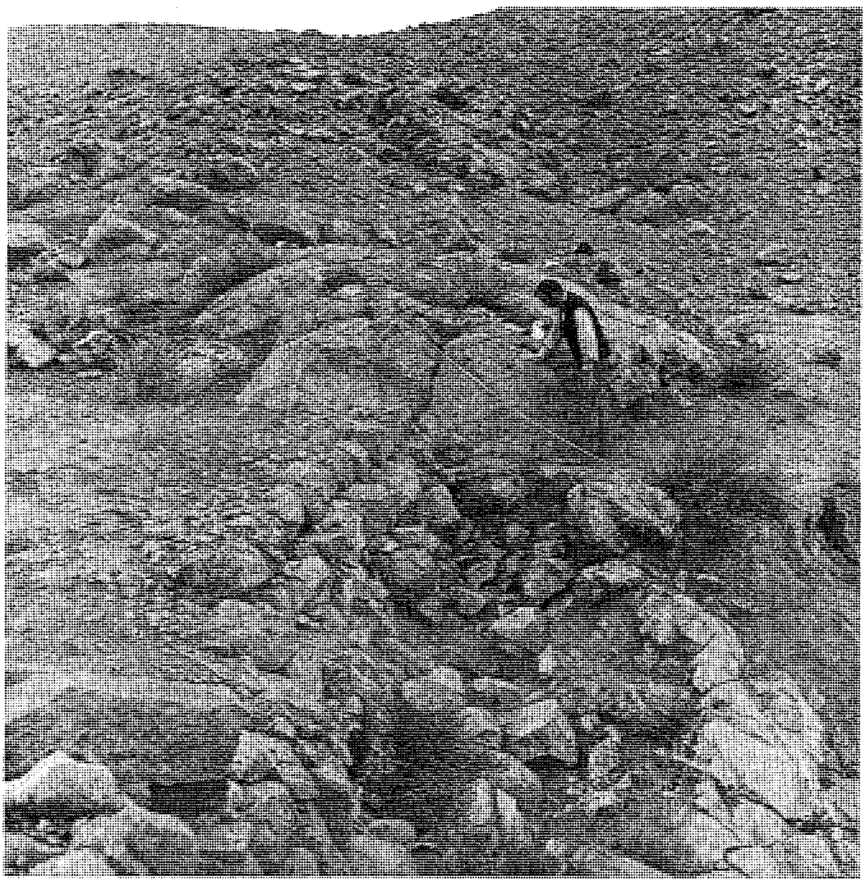
The most continuously exposed, and most characteristic, section of the Middle Shaly Facies is that along the section E traverse (Text-figs. 2, 3) east of Merbah el Oussif. Here overgrazing and the generally dry climate have combined to produce a nearly totally exposed section on the ridge crest where even the least resistant shale can be measured and studied.

Shale and siltstone of the facies generally have siliceous cement, are olive green, greenish gray, or greenish brown gray, and have interlaminated sandstone or carbonate units. Shale beds generally weather to form debris-covered belts on slopes and saddles on the ridges. The more calcareous and sandy units weather to form slabs or small plates and some of the more fossiliferous units are armoured with fossil debris intermingled with resistant platy fragments. Shale appears similar to that of the lowest beds exposed north of Baten beni Zid and to shales interbedded with younger units as well.

Carbonate units in the shaly beds occur as tongues of debris from laterally equivalent dolomitic biohermal complexes, as sheetlike beds of fossiliferous bioclastic limestone or dolomite, and as numerous bioherms from a meter or so across up to several meters thick and tens of meters in maximum dimension. Bioherms vary from limestone to dolomite but are more commonly calcareous close to the large complexes and more dolomitic at some distance into the shale section. Bioherms and the immediately surrounding shale beds are the most fossiliberous parts of the facies, as well as the most consistently fossiliferous part of the entire exposed Permian section in the Djebel Tebaga region. Bioherms range from those dominated by columnar stromatolites or phylloid algae to those dominated by sponges, massive tabulate corals, and bryozoans. Matrix in the sampled bioherms is micritic and somewhat argillaceous and indicates that the carbonate lenses accumulated in a low energy environment.

Brown-weathering, ferruginous sandstone is common in the lower part of the Middle Shaly Facies on the back slopes of Baten beni Zid and the low ridges west of Merbah el Oussif. Some beds 3 or 4 meters thick in the basal section demonstrate the abrupt lenticularity of these detrital units, terminating in some instances in nearly vertical faces against biohermal carbonate lenses. Other sandstone beds are considerably wider spread, particularly those interbedded with olive green shale. Coarse sandstone units record abnormal high-energy currents in the dominantly low energy shale and carbonate environments. Cut-and-fill structures, crossbeds, clasts of shale and limestone, and channeled bases are typical of most sandstone units. Some of these sandstone lenses have poorly preserved plant fragments and a few have limited burrows and other trace fossils.

In the Merbah el Oussif area the Middle Shaly Facies is from 200 to 225 meters thick. It contains an extraordinarily rich and well-preserved fauna dominated by calcareous sponges which are appreciably more varied in the shales than in the bioherms. Nevertheless, *in situ* stromatoporoid-like sponges



TEXT-FIGURE 7.—Small bioherms exposed near the Merbah el Oussif road in the southern part of the pass. The road is between the bioherm in the foreground and that one designated with the white 3. The latter bioherm is one being studied by Driggs in a related investigation.

(Termier and Termier, 1973) are quantitatively important frame builders together with diverse algae and a tabulate coralline superficially similar to the coral *Michelinia* (Plate 1, figs. 3-6). The general assembly of rocks and fossils suggests deposition well below wave base for all of the many dozens of bioherms that we examined. The fusulinacean *Yabeina* is common to abundant at many levels, whereas *Neoschwagerina* is lacking or very rare here. These circumstances suggest that the Middle Shale Facies may be younger than much of the Saikra Biohermal Complex (Text-fig. 3).

Both the lower and upper limits of the Middle Shaly Facies are gradational, interfingering with adjacent carbonate facies (Text-fig. 8) so that the tracing and correlating of stratigraphic boundaries was in many places impractical.

TEXT-FIGURE 8.—Abrupt gradation of a sandstone and shale section into the Upper Bioherm Complex toward the right. Exposures are along section B traverse trail pass north of the village of Haïg el Djemel, immediately south of and below the overlapping Cretaceous rocks east of Kef en Nsoura.

Upper Biohermal Complex.—A thick biohermal dolomite south of Merbah el Oussif is apparently equivalent to the upper part of the Shaly Facies of the more easterly section (Text-fig. 3). This biohermal and bedded limestone sequence (beds 11 to 23, section B) attains a thickness of more than 160 meters in the most westerly exposures (Text-figs. 2 and 3) and is termed the Upper Biohermal Complex.

At the western end of Djebel Tebaga the uppermost biohermal limestones apparently pass abruptly into variegated, marly shales containing many mollusks, oncolites (Plate 2, fig. 1), and martinioid brachiopods. We extend this shaly facies upward to the base of the dominantly redbed sequence and include up through bed 27c of our section B. The beds have been named Bellerophon Limestone by Mathieu (1949) and subsequent geologists, but they contain very little limestone. The upper shale-rich beds are about 23 meters thick in section B. The lower part of this sequence has provided us with a single specimen of *Waagenoceras cf. mojsisovicsi,* an occurrence noteworthy because it indicates an extraordinarily long range of the species, which was found also in the Lower Biohermal Complex of section F, some 300 meters lower.

The southern ridge former of the Djebel Tebaga bordering the broad alluvial plain was termed Upper Tebaga Dolomite by Mathieu (1949). It lies in the upper part of the local range of *Yabeina.* Evidence of the fusulinaceans suggests that the eastern and western parts of this southern ridge are formed by quite different stratigraphic sequences brought into juxtaposition by a large fault.

West of Denguir hill the outer ridge-forming dolomite is 30 to 75 meters thick. It gradually diminishes in prominence until it grades into variegated shales and thin beds of limestone and sandstone, the "Bellerophon" beds of authors, before it passes under the Cretaceous cover (Text-fig. 2).

Saikra Biohermal Complex.—To the east along the southern front of Djebel Tebaga the ridge is formed of prominent hills known locally as Denguir, Djebel Tata, Djebel Souinia, and Djebel Saikra (Text-figs. 4, 6). Here the ridge former is a sequence of dolomite and limestone 100 meters thick dominated by *Neoschwagerina* (Text-fig. 3). The lithologic and faunal distinctness of these rocks suggests that they are different from, and probably older than, the Upper Biohermal Complex to the west, and are possibly fault isolated from northern and western exposures. Consequently we are designating the eastern facies the Saikra Biohermal Complex (Text-fig. 3). The complex is thickest and most continuously exposed in the Djebel Saikra and Djebel Souinia areas, but is more or less continuously mappable westward through Djebel Tata to Merbah el Tebaga. The resistant complex also caps Denguir, west of the pass. West of Denguir the thick carbonate units appear to thin and form only low discontinuous hogbacks.

Lateral continuity across the eastern part of Merbah el Guettat is interrupted by faults which offset some of the distinctive brownish dolomitic units. However, there seems to be no significant fault in the pass through which the Metameur-Toujane road has been constructed. Some minor faulting and offset of the hogback are also observed in the ridge east of Merbah el Tebaga. Continuity of individual carbonate beds across the broad alluvium-filled valley of Merbah el Tebaga is questionable. Sections are sufficiently similar on either side of the pass, however, that lateral equivalence of the complex seems certain.

The top of the complex is not exposed east of Merbah el Oussif because young alluvial deposits lap up onto the back slope of the hogbacks. The thickest exposed section, however, is section G in the Djebel Souinia area with approximately 390 meters of interbedded dolomite, limestone, and minor shale and sandstone. On Denguir the complex is approximately 340 meters thick in section I, but neither the base nor the top is exposed.

Carbonate tongues at the top of the complex in easternmost exposures appear to lens out along strike, for several distinctive massive carbonate biohermal units near the top of section G thin when traced westward, and ultimately have no topographic expression. The younger the carbonate unit the less is its western extent, particularly along the south flank of Djebel Souinia.

A small, well-preserved bioherm in the lower part of the upper complex was sampled for comparison with those of the Middle Shaly Facies and the Saikra Biohermal Complex. This upper bioherm is similar to the two other bioherms which were examined in detail and has a matrix of fine micritic carbonate around a frame of stromatolitic algae, tabulate corals, sponges, and bryozoans (Plate 1, figs. 3, 5, 6). Martinioid brachiopods and some mollusks are accessory as in other bioherms. Oncolitic algae are associated with the bioherm and also occur with smaller dolomitized bioherms in the upper part of the complex. Large fusulinaceans occur in the lower part and are particularly abundant in beds immediately underlying the lower bioherms.

EXPLANATION OF PLATE 2

SANDSTONES, ONCOLITES, AND REPTILIAN FOOTPRINTS FROM PERMIAN ROCKS OF DJEBEL TEBAGA

FIG. 1.—Oncolitic algal carbonate unit in the upper part of the Upper Biohermal Complex. Unit 27a of section B.

FIG. 2.—Pelycosaur tracks on the lower side of a block of Cheguimi Sandstone as found near the top of section B, unit 53, southwest of Halg el Djemel. Pencil at the bottom provides scale. Block is approximately 1 m long.

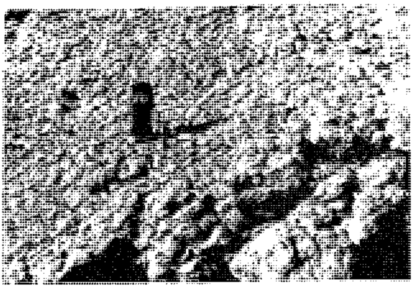
FIG. 3.—Mudstone clasts in sandstone block of Djebel Saikra Biohermal Complex. Section G, unit 27. Scale is approximately 15 cm long.

FIG. 4.—Marked angular unconformity of Cretaceous rocks on Upper Biohermal Complex and Cheguimi Sandstone. Prominent sandstone ledge is unit 29 of section B. Unit 27c, top of the Upper Biohermal Complex, forms the ledge to the right of center, below unit 29.

FIG. 5.—Micro-cross-laminated sandstone and burrowed sandstone, unit 46, section B, Cheguimi Sandstone south of Halg el Djemel.

FIG. 6.—Burrowed light gray sandstone in redbeds in Cheguimi Sandstone. Unit 42, section B, southwest of Halg el Djemel.

PLATE 2



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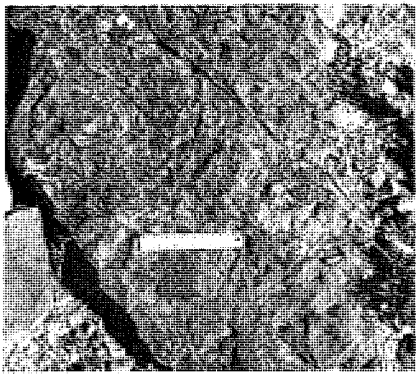

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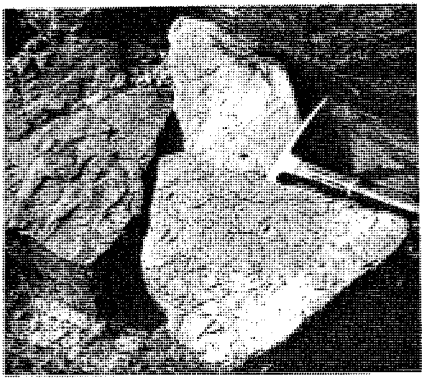

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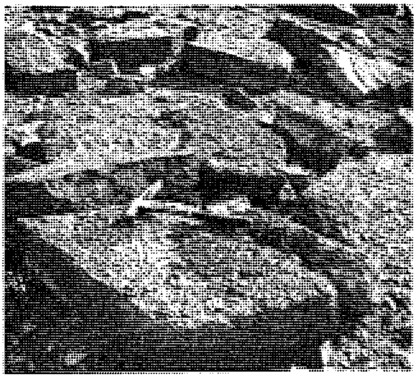

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Several beds of spectacular oncolites (Plate 2, fig. 1) occur in the upper tan and dolomitized part of the complex. Many of the oncolites are biscuit shaped to hemispherical and range to well over 3 cm in diameter. They weather free of an argillaceous to calcareous matrix and have been transported far down Oued Halg el Djemel to the east.

Occurrence of similar faunas in the Saikra and Lower Biohermal complexes suggest that these two may be fault-repeated slices of a large biohermal complex. The Saikra complex appears to rest on Middle Shaly Facies rocks which are younger than the Saikra complex. Additional field work may help unravel structural relationships and document what now appears to be thrust-repeated slices within the Permian section.

Cheguimi Sandstone Facies.—Mathieu (1949) included in the Cheguimi Sandstone (the highest Permian unit in the area), the red and green sandstone, siltstone, and shale, and the thin interbedded carbonate units exposed southwest of Halg el Djemel at the base of the Dahar escarpment in the Cheguimi Gorge vicinity. We measured a single section (section B, units 27 through 54) of the lower 90 meters of the unit for stratigraphic control of fossil localities in the thin marine beds of the lower part of the mainly nonmarine redbed section.

Dark reddish brown to medium gray silty shale and siltstone dominate the lower part of the redbeds (Text-fig. 3). These argillaceous rocks form slopes between the more resistant thin- to thick-bedded light gray, pink, or brown sandstone beds and the somewhat less resistant thin calcareous yellow brown and green shale and limestone or dolomite.

One key sandstone bed, bed 20 of section B, forms a light gray cliff and is the distinctive ledge beneath the Cretaceous angular unconformity (Plate 2, fig. 4) as seen from the east over the souk at Halg el Djemel. The sandstone has a channeled base and shows some internal lenticularity and crossbedding. Sandstone beds higher in the section are less continuous, and most are thinner, usually less than one or two meters thick. These units show considerable cross bedding, ripple marks, rib-and-furrow structure (Plate 2, fig. 5), and some contain impressions of wood fragments. Some of the thinner units are burrowed (Plate 2, figs. 5, 6) and, with associated rocks, suggest a marginal marine to tidal flat environment of deposition for at least the lower part of the Chequimi Sandstone.

The greenish marine units contain a variety of trace fossils and small bivalves; one greenish to yellow brown shale 44 meters above the base contains an abundance of the small fusulinacean *Dunbarula.* Some of the reddish silty and sandy beds have been intensely bioturbated and their original internal structure is largely destroyed. Trace fossils are also common in some of the thin lenticular sandstone beds in the upper part of our measured section. Some beds show common arenicolitid vertical and U-shaped burrows; others exhibit less well-organized internal traces. A single slab of sandstone furnished well-preserved reptilian tracks from 84 meters above the base of the redbed section. These tracks were identified for us by Dr. Donald Baird of Princeton University as a Permian pelycosaur similar to *Edaphosaurus.* Other blocks showing poor impressions occur at the same general level near the top of our traverse, but only the single block with good footprints (Plate 2, fig. 2) was collected by us and officers of the Tunisian Geological Survey.

APPENDIX 1

Measured Sections

Matmata Quadrangle, Tunisie Feuille No. XCI, 1:100,000
Service Géographique de l'Armée, Paris, 1906

Section A

Isolated exposure along Medenine-Matmata highway along base of the Oum el Afia escarpment, 4 km SE of Toujane.

Bed number	*Description*	*Thickness in meters*
9	Sandstone, dark brown, with orange pebbles, mainly covered.	9
8	Shaly, covered.	10
7	Dolomite, orange, with phylloid algae.	2
6	Shale, red and green, with thin beds of dolomite, limestone, and sandstone.	30
5	Dolomite, sandy and limestone with sponges, poorly preserved.	13
4	Covered, shaly.	5
3	Limestone, dolomitic, and sandstone: *"Chusenella," Neoschwagerina,* and *Yabeina* (24745).	3
2	Sandstone, some sedimentary deformation, hard, thin bedded, has been cored by earlier geologists for paleomagnetic determinations.	3
1	Sandstone and siltstone, irregularly bedded with thin beds of dolomite, weathers reddish buff, base covered by alluvial plain.	7+

Section B

Base of escarpment capped by Cretaceous strata west of Merbah el Oussif

Bed number	*Description*	*Thickness in meters*
Cheguimi	Sandstone	
54	Shale, red, caps knoll.	3+
53	Sandstone, dark reddish brown; pelycosaur tracks (Plate 2, fig. 2), cross lamination, current lineation, clay-pebble molds, scoured base (Faul 39).	1
52–49	Cover (red soil), interrupted by one major and two minor reddish brown sandstone ledges. Major ledge exhibits cross lamination and deformed lamination; minor ledges have abundant dwelling burrows and rib-and-furrow structure.	21.8
48	Limestone, earthy, tan to greenish gray.	0.1
47–45	Shale, red (lower) to grayish green (top); minor reddish brown sandstone beds with vertical dwelling burrows and rib-and-furrow structure (Plate 2,, fig. 5).	7
44	Sandstone, reddish brown, burrowed, lenticular (Faul 38).	1
43–36	Shale, red, interrupted by one major and several minor sandstone beds. Major sandstone has cross lamination (de-	39

	formed in places); several minor sandstone beds have rib-and-furrow structure; one has dwelling burrows (Plate 2, fig. 6).	
35–32	Shale, red, including two thin, yellowish gray marlstone beds.	3.2
31	(b) Shale, yellowish brown, capped by thin, yellowish gray, sandy dolomite. *Dunbarula* bed (13537) (24729) midway through unit; dips 11° south (Faul 34a).	1.5
	(a) Shale, greenish brown, with minor ledges of drab marlstone near top.	1.5
30	(c) Shale, red, interrupted by two reddish brown sandstone beds with rib-and-furrow structure.	13.5
	(b) Limestone, micritic, yellowish gray; forms two thin beds separated by red shale; lower bed contains small valves.	0.7
	(a) Shale, dark reddish brown.	3.1
29	Sandstone, light gray, prominent in photo views of Permian-Cretaceous unconformity (Plate 2, fig. 4); cross lamination; broad channel fill at base.	6.7
28	Shale, dark reddish brown; yellowish brown sandstone in upper part contains beaded trace fossils, plant (?) molds, and irregular ripple marks.	12.1
27	(e) Sandstone, dark brown (lower) to pinkish gray (upper); lenticular.	0.9
	(d) Shale, red and green; yellowish gray marlstone forms minor, discontinuous ledges in upper part.	3.7
Djebel Tebaga Biohermal Complex		
	(c) Limestone, yellowish gray, crowded with phylloid algae; scattered fenestrate bryozoans.	0.9
	(b) Sandstone, yellowish gray, low ledges, laminated; scattered vertical burrows.	1.3
	(a) Marlstone, yellowish brown; oncolites dominate lower part (Plate 2, fig. 1); upper part nonresistant, consisting of poorly sorted skeletal debris.	3.7
26	Shale, red, including three sandstone beds; lower sandstone includes fossil debris; middle sandstone has prominent load-deformation structures; upper sandstone bioturbated (Faul 31).	7.2
25	(b) Shale, green to yellowish brown, with martiniod brachiopods.	3
	(a) Dolomite, light brown, massive, with large lucinoid (?) pelecypods.	0.4
24	Shale, greenish brown, with thin beds of fossiliferous limestone *Waagenoceras* cf. *mojsisovicsi; Dunbarula; Chusenella;* neoschwagerinids (24772, 24771).	6.7
23	Bioherm (Driggs #2); passes abruptly into gray, even-bedded limestone.	6
22	(e) Limestone, even bedded, poorly sorted skeletal material, including fusulinaceans, crinoid columnals, tabulate	6

	corallines, bryozoans, and martinioid brachiopods. Includes small bioherm. *Yabeina, Chusenella, Dunbarula* (24769).	
	(d) Cover; yellowish brown soil.	4.5
	(c) Limestone; poorly sorted skeletal material, including scattered echinoid spines and martinioid brachiopods.	3
	(b) Limestone; coquina of *Yabeina, Chusenella, Dunbarula* (24766, 24767, 24768).	0.6
	(a) Limestone; even bedded, poorly sorted skeletal debris (Faul 27).	3
21–11	Bioherm complex, not examined in detail; thick bedded, draped, and very lenticular, limestone and dolomite and interbedded wedging thin beds of brown sandstone; carbonate beds vuggy, recrystallized with "ghosts" of fossils; estimated on map.	138
10	Sandstone, reddish brown, irregularly bedded.	12
9	Bioherm complex, upper ridge former of Baten beni Zid, of thick-bedded draped and lenticular recrystallized dolomite with interbedded thin units of shale and brown sandstone.	220
8	Sandstone, brown, with leptodid brachiopods and arthropod tracks.	3
7	Limestone, marly.	3
6	Limestone, bedded.	3
5	Bioherm complex, thick bedded, forms lower rim of Baten beni Zid escarpment.	30
4	Shale, marly, with leptodid brachiopods and sponges.	8
3	Sandstone, brown, massive at top.	19
2	Sandstone, thick-bedded, crinoid stems.	8
Oum El Afia Shale (?)		
1	Shale, green brown, contains leaves of land plants, *Chusenella* (13536).	20+

Section C

West of Merbah el Oussif

Bed number	*Description*	*Thickness in meters*
Djebel Tebaga Upper Biohermal Complex		
21	Limestone, bioherm, vuggy with gypsum fillings, dips under alluvial plain, fusulinaceans: *Chusenella* (24765)	2.5+
20	Shale, covered.	4.5
19	Limestone bioherm with sponge-algal fabric, rugose corals, *Waagenoceras* cf. *mojsisovicsi, Yabeina, Chusenella, Dunbarula.* (Same horizon and locality as bed 32, section J and bed 23, section B) (24764, 24763).	7
18	Limestone, rubbly, a few fenestrate Bryozoa; *Chusenella* (24762).	5
17	Limestone, bioherm, yellowish, with sponge algal fabric.	10

Middle Shaly Facies

16	Shale, greenish, gray and red, some flaggy sandstone and flat-pebble beds, a few small *Bakevellia* clams, same as bed 28, 29, section J.	35
15	Limestone and marl, not very fossiliferous, foreslope of main Tebaga ridge.	40
14	Limestone, unfossiliferous.	12
13	Shale, nodular, relatively unfossiliferous, wedges out in massive dolomite immediately to the west.	3
12	Sandstone, slabby, ferruginous, wedges out in massive dolomite to the west.	3
11	Shale, marly, rich fauna of sponges, snails, brachiopods, and clams, mainly in lower part interbedded with several brown bioherms, *Yabeina, Neoschwagerina, Dunbarula, Chusenella, Pseudogastrioceras sosiense* (24761) (24760).	105

Djebel Tebaga Lower Biohermal Complex

10	Limestone, brown, irregular, just above foreslope of Baten beni Zid hogback; same as bed 10 of section B (base of section).	12

Section D

West side of Merbah el Oussif

Bed number	*Description*	*Thickness in meters*
23	Sandstone, shaly, brown, forms two outlying buttes just south of the mouth of the Merbah, previously mapped as Triassic.	23+
22	Covered.	30
	Djebel Tebaga Upper Biohermal Complex	
21	Dolomite, vuggy, reef complex, makes the southern front of the Tebaga in this area.	40
20	Dolomite, brown.	1
	Middle Shaly Facies	
19	Shale, red, and marl with sponges (19C).	15
18	Dolomite, biohermal.	12
17	Marl with sponges.	5
16	Dolomite, bioherm.	3
15	Marl and limestone bioherms, whole sequences overlapped abruptly westward by shale of bed 16, section C.	30
14	Dolomite bioherm.	2
13	Marl with sponges.	5
12	Dolomite, bioherm with crinoid stems.	14
11	Marl with sponges and fusulinaceans.	32
10	Dolomite buff, unfossiliferous, vuggy, ridge former.	11
9	Shale, marly, with sponges, fusulinids, and two or more biohermal zones, same as bed 11, section C.	105

Djebel Tebaga Lower Biohermal Complex		
8	Dolomite, reef complex, very massive and lenticular, with lenses of sandstone, ghosts of fossils, Baten beni Zid hogback (base of section).	10+

Section E

Along divide just east of Merbah el Oussif

Bed number	*Description*	*Thickness in meters*
Djebel Tebaga Upper Biohermal Complex		
30	Bioherm, recrystallized, dips under alluvium.	25+
29	(f) Calcarenite, crinoid debris, upper beds cross laminated; grades abruptly to east into bed 28.	2
	(e) Bioherm, patchy alteration, fusulinaceans at top; *Dunbarula* (13543).	9
Middle Shaly Facies		
	(d) Shale, grayish green, largely covered; selenite crystals.	4
	(c) Sandstone, ferruginous; lower part ledge forming, with prominent clay-pebble molds; upper part thin bedded and nonresistant.	4
	(b) Shale, with thin beds of sandstone and scattered small bioherms.	4.6
	(a) Sandstone, dark reddish brown, prominent clay-pebble molds; scattered small bioherms; abrupt lateral gradation into bed 28.	9
28	Bioherm, forms ridgecrest of the mountain; dips 23° southeast (Faul 18.2).	3
27	Shale, red (upper) to grayish green (lower), with slabby sandstone at top; a few thin slabs of brown calcarenite with large pterioid clams, good sponges; *Chusenella* (24759).	12
26	Limestone, discontinuous series of bioherms including Driggs' number 3 (Faul 17) (Text-fig. 7); interbioherm marl and calcarenite with dasycladacean debris, small pterioid clams and oncolites; *Dunbarula* (13542); *Yabeina* (24758).	6
25	Shale, greenish gray, contains a small bioherm in upper part (Faul 16).	25
24	Sandstone, brown, discontinuous, terminates abruptly against an equivalent bioherm (Faul 15a).	11
23	Shale, marly, contains many sponges, a few gastropods.	3
22	Limestone, bioherm lens, sponge-algal (Faul 15); *Dunbarula* (13540).	5
21	Marl with many sponges and a few gastropods; *Yabeina, Chusenella* from 21-26 (13541) (24757).	6
20	Limestone, discontinuous bioherm lenses, interbioherm coquina of large fusulinaceans (Faul 14, 14a).	9

19	Shale, olive buff, few fossils.	12
18	Limestone rubbly in swales, lenses of large fusulinaceans, terminates abruptly into flank of bed 16; *Yabeina, Chusenella, Dunbarula* (24756).	0.2
17	Shale, yellowish, poorly exposed.	1
16	Marl with discontinuous bioherm lenses, many sponges (Faul 13 at top), forms high point on divide.	10
15	Limestone, bioherm lens, brown, with sponges and algae (Faul 12).	8
14	Marl, very fossiliferous, mainly sponges, one or more small bioherm lenses; *Dunbarula, Yabeina, Chusenella,* neoschwagerinid, schwagerinid (13539) (24755).	20
13	Limestone bioherm lenses with sponge fabric (Faul 11).	1
12	Shale, covered.	14
11	Limestone, recrystallized, discontinuous, sponges abundant around margins (Faul 10).	1.6
10	Shale, covered; neoschwagerinid, schwagerinid (13538), *Yabeina, Chusenella* (24753) from 10A-12A.	14
9	Sandstone, brown, with thin calcareous layer at top containing fusulinaceans; abundant ramose feeding trails on one surface; dips 32° south; *Yabeina* (24751).	1.6
Djebel Tebaga Lower Biohermal Complex		
8	Limestone, massive cliff former, main ridge of Baten beni Zid, estimated at base of section.	180

Section F

Northwest slope of the eastern end of Baten beni Zid mountain near Nouveau Toujane Souk. Beds 1 and 2 are near the axis of a local anticline where dips are variable.

Bed number	*Description*	*Thickness in meters*
Djebel Tebaga Lower Biohermal Complex		
8	Dolomite, saccharoidal, vuggy, gray, with several lenses of slabby brown sandstone draped around reef knobs, dolomite to top of unit.	120
Oum El Afia Shale (?)		
7	Shale covered, *Waagenoceras mojsisovicsi* collected in 1967 from this (?) bed.	50
6	Limestone, small discontinuous bioherms.	10
5	Shale, covered, marly.	32
4	Limestone, gray, with sponges, excellent large fusulinaceans at base; *Neoschwagerina, Hemigordiopsis* (24750).	3
3	Limestone, with sponges and algae (Faul 45).	36
2	Shale, marl, mainly covered; *Neoschwagerina* (24749) and sponges.	47
1	Limestone, brown, with poorly preserved, large spheroidal fusulinaceans.	7

Section G

East end of Djebel Tebaga range between Djebel es Souinia and Merbah Grouz. Beds dip south 30-45°

Bed number	*Description*	*Thickness in meters*
Saikra Biohermal Complex		
36	Limestone, recrystallized, dips below alluvial plain.	35+
35	Cover.	5
34	Limestone; poorly sorted skeletal material including crinoid columnals, echinoid spines, bryozoans, brachiopods, *Dunbarula, Neoschwagerina* (13564) (13565). Abrupt lateral change a few meters east to beds dominated by molds of large martinioid brachiopods at flank of bioherm.	14
33	Cover.	13
32	Bioherm, fabric indeterminate, reddish purple alteration patches common in lower part. Gives way abruptly to bedded sequence to west.	26
31	Limestone, prominent bedding, poorly sorted skeletal material including brachiopods and crinoid columnals.	1
30	Bioherm (Text-fig. 6); small sponges and tabulates, columnar stromatolites, fenestrate bryozoans, *Enteletes,* leptodid (Faul 70).	2.5
29	Marlstone, including small bioherms of columnar stromatolites; small spiriferoids common.	3.5
28	Limestone; poorly sorted skeletal material including echinoid spines, small brachiopods, bryozoans; lower part has scattered yellowish orange mudstone clasts; lenticular concentrations of large fusulinaceans at top; *Neoschwagerina, Chusenella, Dunbarula* (13563).	0.2
27	Sandstone, fine grained, grayish orange; thinly laminated and nonresistant; scour-and-fill bedding, with up to 22 cm relief on scour surfaces; some contorted lamination. Scattered lenses of pale brown, sandy, skeleton-rich carbonate including oncolites, gray mudstone clasts, large high-spired gastropods and molds of large plant (?) fragments as much as 8 cm wide and 50 cm long.	3.5
26	Sandstone, fine grained, light brown; ledge forming; includes parallel lamination, cross lamination, scour-and-fill bedding, and crescentic ripple marks.	1.5
25	Cover.	2.5
24	Limestone; basal part poorly sorted skeletal material rich in *Bakevellia* with many tabular clasts of yellowish orange lime mudstone; clasts typically 3 cm x 2 cm x ½ cm, containing rare fusulinaceans and echinoderm plates. Main part of unit is coquina of *Dunbarula* (13562).	0.3
23	Cover.	3.5
22	Limestone; poorly sorted skeletal material, predominantly	0.5

	fusulinaceans, with echinoid spines and large high-spired gastropods. *Dunbarula, Chusenella* (13561).	
21	Cover.	1
20	Limestone, olive gray to yellowish brown; fusulinacean coquina, to poorly sorted skeletal material including oncolites and crinoid column segments several cm long. Unit thickens laterally as subjacent one thins. *Dunbarula, Chusenella* (13559) (13560).	4
19	Bioherm, fabric indeterminate; grades laterally into unit 20. (Faul 69).	12.5
18	Cover.	5
17	Limestone; poorly sorted skeletal material including echinoid spines, crinoid column segments, *Schizodus,* and brachiopods. Lenticular concentrations of oncolites in lower part. Dips 40° south (Faul 68).	1
16	Marlstone, grayish orange, nonresistant. Bryozoans and echinoid plates; very large pelecypod valves at base (Text-fig. 6).	4
15	Bioherm; sponges, bryozoans, and columnar stromatolites. Grades abruptly into bedded carbonate in both directions along strike. Same horizon as Driggs bioherm 1 on next spur east (Plate 1, fig. 1).	3
14	(b) Limestone; fusulinacean coquina. *Dunbarula, Neoschwagerina* (13557) (13558).	2.5
	(a) Limestone; poorly sorted skeletal material including large bellerophonts and high-spired gastropods; algal crusts, common on shells.	0.3
13	(b) Sandstone, fine grained, grayish orange, thinly laminated and nonresistant.	4.5
	(a) Sandstone, fine grained, light brown; ledge forming. Scattered yellowish orange clasts; localized contortion of laminae (45 cm amplitude); scour-and-fill bedding, both within unit and at base, with as much as 45 cm relief on scour surfaces; large flute casts at base. Grades abruptly into upper part of small bioherm 100 m to west.	3.5
12	(g) Cover. Red soil; local exposures of red mudstone in upper part. Algal encrusted fossils; gastropods with barnacle borings. Laterally equivalent to part of small bioherm 100 m to west.	1
	(f) Limestone; abundant skeletal material, poorly sorted, including *Bakevellia* and high-spired gastropods.	0.4
	(e) Cover.	1.1
	(d) Limestone, with prominent yellowish orange clasts of lime mudstone. Clasts are tabular (4 cm long), concentrated in lower part; upper part largely fusulinacean coquina; top surface strewn with echinoid spines, high-spired gastropods, and bellerophonts.	0.2
	(c) Cover	2.5

	(b) Limestone; lower part a coquina of *Dunbarula;* upper part poorly sorted skeletal debris including small bellerophonts, *Bakevellia,* echinoid plates and spines (Faul 66).	0.5
	(a) Cover; grayish orange soil.	3
11	Limestone; lower and upper parts of well sorted small fusulinaceans; middle part poorly sorted skeletal debris including gastropods, echinoid spines, crinoid column segments, and oncolites. *Dunbarula, Chusenella, Neoschwagerina* or primitive *Yabeina* (24748) (13551) (13552). Dips 45° southeast.	12
10	Limestone, biohermal; abundant columnar stromatolites (Faul 65).	13
9	Marl, red shale and platy sandstone with thin brown limestone at base.	12
8	Limestone; many sponges and columnar stromatolites.	6.5
7	Shale, red at top, with thin beds of sandstone (Faul 59).	55
6	Limestone, slabby; the chambered sponge *Verticilites* is common. Grades locally into bioherm lenses, *Dunbarula* coquina, *Chusenella?* (24747) (13550) at extreme top. Dip 34° southeast.	5
5	Marl, rich in sponges and bryozoans, contains several beds of platy calcarenite.	25
4–1	Limestone and shale; this is a reef complex of lensing sponge-algal-bryozoan beds with lenses of marly interreef shale bearing abundant sponges, some mollusks, and crinoid columns; dips 37° southeast (Faul 53 at top); *Neoschwagerina* (bed 3) (24746).	100

Section H

South slope of hogback ridge east of Merbah el Guettat

Bed number	*Description*	*Thickness not recorded*
Saikra Biohermal Complex		
6	Limestone, dark gray; abundant skeletal debris including small fusulinaceans and dasycladaceans (?); dips 40° south; outcrop beside road at edge of alluvial plain. About equivalent to upper part of bed 35, section G.	
5	Bioherm, small.	
4	Cover; yellowish brown soil.	
3	Limestone, ledge forming, poorly sorted skeletal material including large *Enteletes, Yabeina,* bryozoans, oncolites; dip 55° south.	
2	Cover; yellowish brown soil.	
1	Bioherm complex, major ridge former; frame indeterminate; crinoid stem segments 5 cm diameter and 12 cm long at ridge crest; leptodid; same horizon as bed 32 of section G.	

Section I

Northwest slope of Denguir hogback one kilometer west of south entrance of Merbah el Tabaga

Bed number	*Description*	*Thickness in meters*
Saikra Biohermal Complex		
19	Limestone, pinkish gray, recrystallized; dips 31° south, under alluvial plain.	40+
18	Limestone, light olive gray, recrystallized, vuggy in places, poorly defined thick beds; major ridge former.	50
17	Cover; surface debris largely from bed 18 but includes plates of grayish red sandy calcarenite and sponges.	30
16	Marlstone, grayish orange, lacking good bedding; yields blocky rubble; ramose bryozoans (?) and sponges.	6
15	Bioherm, yellowish brown, patches of sparry calcite; thickens to west; *Martinia; Neoschwagerina, Dunbarula, Chusenella?* (13548).	4.5
14	Cover; rubble from bed 15.	15
13	Shale, green below, red above; red interval includes iron-cemented sandstone bed with feeding burrows; green interval includes thin iron-stained beds of skeletal debris notable for prominent echinoid spines.	2
12	Cover; rubble of brown blocks, and green slabs of poorly sorted skeletal debris including gastropods, echinoid spines, and oncolites, *Neoschwagerina, Dunbarula, Chusenella* (13547) (24774) (24775) (Faul 3).	21
11	Bioherm, light olive gray; local lens, with skeletal debris on flanks (Faul 2).	3
10	Marlstone, forming rubbly slope interrupted by low ledges; sponges and bryozoans.	11
9	Bioherm, frame indeterminate.	7.5
8	Marlstone, nonresistant, nodular; forms slope with much rubble and some grayish orange soil; tabulate corals, bryozoans, small sponges, small brachiopods, fusulinaceans.	3
7	Limestone, light olive gray, scattered skeletal material; forms ledge lacking good bedding; *Chusenella*(?) (13546).	4.5
6	Cover; probably a continuation of marlstone below.	21
5	Marlstone and interbedded shale; forms slope interrupted by low ledges; yields rubble of grayish orange slabs; large fusulinaceans, sponges, tabulate corals, rare pectinaceans and gastropods; dips 35° south; *Neoschwagerina, Chusenella?* (13545).	11
4	Limestone, light brown, scattered small fossils; low ledges.	6.5
3	Bioherm, frame indeterminate. Yellowish weathered interval midway through unit contains *Chusenella* (?) and schwagerinids (13544).	15
2	Shale, covered with grayish orange rubble. Float includes plates of fibrous calcite, and sponges.	12

1	Bioherm, light olive gray, frame indeterminate. Interrupted by lens of greenish gray shale 18 m above base. Upper part of unit mottled with grayish orange patches. Sponges, bryozoans, and small brachiopods. Base covered by alluvium.	75

Section J

Between Merbah el Oussif and Kef en Nsoura

Bed number	*Description*	*Thickness in meters*
Djebel Tebaga Biohermal Complex		
34	Bioherm, gray, frame indeterminate; makes low ridge at edge of broad alluvial plain.	5
33	Cover.	8
32	Limestone, irregularly bedded to biohermal; rugose corals at top; same bed as 19 of section C, and 23 of section B.	10
31	Limestone, oncolitic.	13
30	Bioherm, gray to brown, rubbly outcrop; thickens and thins along strike.	13
29	Shale, red, and interbedded sandstone, fine grained, olive gray to reddish brown, with casts of feeding burrows.	22
28	Shale, grayish green, and sandstone, fine grained, pinkish brown to grayish green. Flute casts and excellent invertebrate trails 6 m above base; large scour-and-fill structures midway through unit; dips 28° south.	42
27	Bioherm, gray (lower)to brown (upper); forms local ridge crest; irregular upper surface reflects relief on biohermal knolls; upper part interfingers with shales to east.	29
26	Bioherms, separated by shaly partings; sponges in shale; bryozoans and small sponges in bioherms.	12
25	Cover; yellowish brown soil with many sponges; unit becomes lost in massive carbonate to west.	1
24	Bioherm, gray; forms ridge crest; approximately equivalent to beds 14 and 15 of section C.	36
23	Sandstone, dark reddish brown; discontinuous exposures; trace fossils; grades into massive carbonate to west (Text-fig. 8); dips 28° south.	26
22	Bioherm, gray; thickens abruptly to east; terminates immediately west of traverse in sharp contact with laterally equivalent dark brown sandstone (Text-fig. 5); probably equivalent to bed 20 of section E.	6
21	Cover, interrupted along strike by scattered exposures of gray bioherms.	31
20	Sandstone, iron stained, cross laminated; discontinuous exposures; wedges out to east against bed 19.	9
19	Bioherm, yellowish gray; forms low rubbly ridge, thickening to east; probably equivalent to bed 15 of section E	3
18	Shale, greenish gray; sponges common; dips 27° south	17.5

17	Shale and scatered brown bioherms (Text-fig. 5); surface littered with sponges, echinoderms, and mollusks; probably same as bed 11 of section C.	8
16	Bioherm complex; Baten beni Zid Formation of authors; not examined in detail.	
	(b) brownish gray carbonate grading upward into brown dolomite, and westward into shale interrupted by brown bioherms as much as 15 m in diameter.	125
	(a) grayish brown to bluish gray carbonate; ridge forming; interfingers with nonresistant units to east.	19
15	Cover, with scattered exposures of thin-bedded, sandy carbonate; laterally equivalent prominent iron-stained sandstone terminates immediately to west; dips 24° south.	3
14	Bioherm complex; lower part tan and vuggy, with sponge "ghosts;" upper part more uniformly resistant, ridge forming, grayish brown to bluish gray; base of Baten beni Zid Formation of authors.	35
13	Sandstone, ferruginous, medium grained, rare clay-pebble molds; some contorted lamination; ledge forming, becoming tan and less resistant at top.	4.5
12	Bioherms, tan to pinkish gray, separated laterally and vertically by pods of brown sandstone; bioherms commonly 3 m thick, with sponge "ghosts."	16
11	Sandstone and interbedded sandy carbonate; low ledges; abundant yellowish brown clay pebbles in tan calcareous matrix.	7.5
10	Sandstone, medium to coarse grained, dark reddish brown, cliff forming, irregular basal contact; lower part laminated, upper part mainly massive; tabular clay-pebble molds common and as much as 10 cm long.	10.5
9	Shale, red; largely covered with rubble from bed 10.	38
8	Sandstone, medium grained, dark reddish brown, cliff forming; lower part laminated, with scour-and-fill structure; upper part massive, with abundant ellipsoidal, pea size, pinkish yellow clay pebbles; dips 23° south	8 8
7	Cover; reddish soil; sponges in lower part.	16.5
6	Bioherm, tan below to pinkish brown in upper part; forms ridge crest.	9.6
5	Shale, greenish gray, with small yellowish brown bioherm in upper part; sponges and tabulate corallines in soil.	21
4	Bioherm, mottled gray and tan.	33
3	Cover.	4
2	Bioherm, recrystallized, lower part light gray, upper part brown.	14

Oum El Afia Shale (?)

1	Shale, grayish green; rare sponges.	26

APPENDIX 2

Collation of Fossil Localities of the 1974 and 1975 Collections
and of Collections by H. and C. Faul

SECTION A

1974 (USNM 309317), bed 3 (=FS-74-T4)

SECTION B

1974 (USNM 309317)	1975 (USNM 315212)	H. & C. Faul
	B-53	CF-39
	B-44	CF-38
31	B-31b	CF-34a
	B-26	CF-31
25	B-25	
24, 24B, 24-2, 24-3, FS-12	B-24	
23	B-23 (Driggs Bioherm 2)	
22	B-22	CF-27
21	B-21	

SECTION C

1974 only (USNM 309317)
(Numbers and horizons generally same as Section D)
21
19, FS-3, FS-10 (=32J)
18, FS-9 (=31J)
16
11, FS-6, FS-7 (=9, Section D)

SECTION D

1974 only (USNM 309317)
(Numbers and horizons generally same is Section C)
23, FS-14
19
17
16
9, 9B (=Bed II, Section C)

SECTION E

1974 (USNM 309317)	1975 (USNM 315212)	H. & C. Faul
A-28, FS-2	E-28	CF-18a
A-27, FS-2	E-27	
A-26, FS-2	E-26 (Driggs Bioherm 3)	CF-17
A-25	E-25	CF-16
A-23	E-23	
A-22	E-22	CF-15

A-21	E-21	
A-20	E-20	CF-14, CF-14a
A-16	E-16	CF-13
A-15	E-15	CF-12
A-14	E-13	CF-11
A-12	E-12	
A-11, 11B-19B	E-11, E-11 to E-19	CF-10
A-10, 10	E-10	

SECTION F

1967	1974 (USNM 309317)	1975 (USNM 315212)	H. & C. Faul
	A-8	F-8	
Waagenoceras	A-7	F-7	
from F-7?	A-6	F-6	
	A-5	F-5	
	A-4	F-4	
	A-3	F-3	CF-45
	A-2	F-2	
	A-1	F-1	

SECTION G

1974 (USNM 309317)	1975 (USNM 315212)	H. & C. Faul
?S-10	G-34	
	G-30	CF-70
	G-23	
	G-20	
	G-17	CF-68
	G-15 (Driggs Bioherm 1)	
	G-14b	CF-67
	G-12d	
	G-12b	
	G-11	CF-66
	G-10	CF-65
S-8	G-8	CF-64
	G-7	CF-59
S-7	G-6	
S-5	G-5	
	G-4	CF-58
S-3	G-3	
S-1	G-1	

SECTION H

1975 (USNM 315212)

Bed 3

SECTION I

1974 (USNM 309317)	1975 (USNM 315212)	H. & C. Faul
FS-13, FS-13a	I-12	CF-3
	I-11	CF-2
	I-10	
	I-7	
	I-3	
	I-2	

SECTION J

1974 (USNM 309317)	1975 (USNM 315212)	H. & C. Faul
23	J-32, 23B-19C	
	J-31	CF-18
	J-27	CF-15
	J-5	CF-43

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