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Artikel: The front ranges of Sierra Madre Oriental, Mexico, from Ciudad Victoria to Tamazunchale
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II. Stratigraphy.

(a) General Observations.

The following formations are exposed in the mapped part of the Front Ranges:

Recent	Alluvium. Caliche, Screes, Rock-Slides.
Late-Tertiary? . . .	Basalt-flows and mesas. Basaltic necks and plugs.
Paleocene	Chalma Shale Tanlajás Sandstone } Chicontepec Formation.
Cretaceous	Tamesí Formation. Mendez Marls. San Felipe Formation. Xilitla Formation. Tamabra Limestone. Lower Cretaceous Limestones (in the northwest).
Jurassic	Upper Jurassic Limestones and Shales (in the south). Olvido Formation Novillo Formation } in the north.
Permian?	Red Beds with basic intrusions.
Carboniferous	Peregrina Formation.
Pre-Carboniferous	Phyllites, Micaschists. Gneiss and granite.

The oldest rocks of the Front Ranges occur in the north, where two lateral valleys, west of Victoria, have exposed the crystalline core of the main anticline. This core is overlain unconformably by a thick series of Upper Palaeozoic strata, cut off by a second unconformity. Then follow more than 2000 metres of Mesozoic sediments, chiefly Cretaceous limestones and marls. The limestones, especially the thick-bedded Tamabra, dominate the Ranges. In the north, the Pre-Cretaceous sediments are partly terrestrial and brackish. In the south, at Tamazunchale, fossiliferous marine sediments of Jurassic age with ammonites occur.

(b) Region of Ciudad Victoria.

Gneiss.

Novillo and Peregrina Canyons have opened the crystalline core, formed of gneiss, gneissic granite and amphibolite. At Novillo, the gneiss is rich in red garnet. The foliation strikes NW and WNW, thus obliquely to the folds of the Cretaceous sediments. The crystalline rocks are cut by green diabase and serpentine and capped by gabbro (Pl. XVII, Section 1—2; Textfig. 2).

At Peregrina, the gneiss dips less steeply, generally to E or NE. In places, it is so slightly metamorphosed that one might call it a granite. Basic and metamorphic rocks are again associated with the gneiss, which is faulted against the Palaeozoic sediments (Pl. XVII, Section 1).

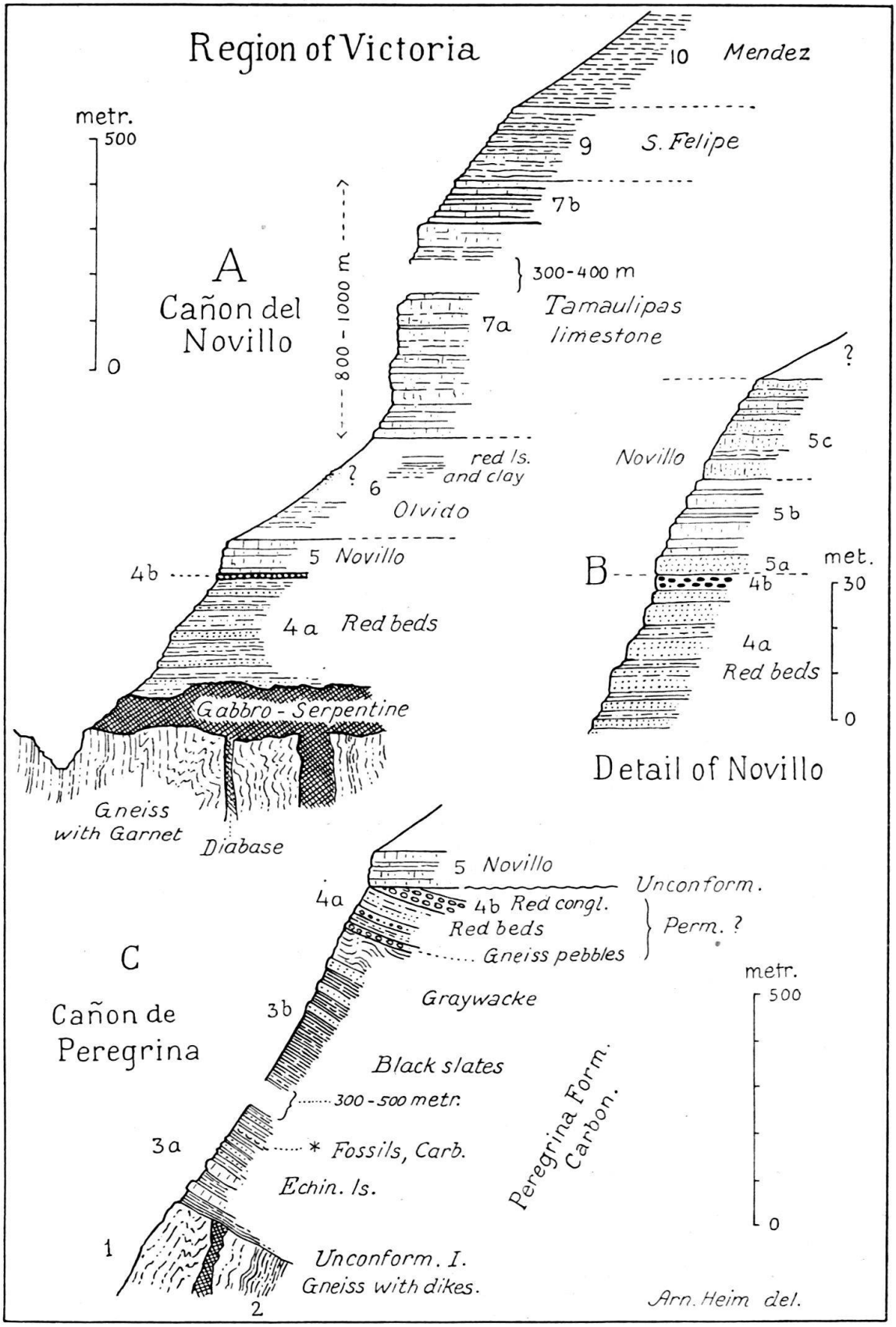

Fig. 2. *Stratigraphic Sections of the Basal Formations in the North.*

Phyllites (Pre-Mississippian).

Boulders of mica-schists and spotted phyllites *(Knotenschiefer)* occur on the trail above Peregrina. The latter, with andalusite, are a typical product of contact-metamorphism. According to Mr. PARKER ROBERTSON, who accompanied me, they come from the higher valley-slope towards Molino (Section 1), and seem to overlie the gneiss; but they are certainly older than Mississippian.

Peregrina Formation (Mississippian).

The Peregrina ranch-houses stand on steeply and intensely folded, dark slates, about 1000 m thick, with beds of greywacke. To the east, in the upper part of the series, there are beds of conglomerate with gneiss-boulders up to the size of one's head, and red quartzite. The uppermost conglomerate-bed forms the base of the overlying Red Beds.

About 1 km west of Peregrina ranch occurs a rough, sandy limestone, dipping west, with echinoderm-fragments. Then follow greywacke and greenish quartzite, overlain by fossiliferous, black, sandy shale. The fossils collected in the creek by Messrs. P. ROBERTSON, J. M. MUIR and the writer were determined by Dr. L. W. STEPHENSON of the U. S. Geological Survey as *Productus semireticulatus* var. *hermosanus* GIRTY, *Spirifer*, *Orthothetes*, *Athyris*, *Spiriferina*, etc., and have been regarded as Pennsylvanian.

According to a letter from the late STUART WELLER (University of Chicago), however, fossils collected by Mr. C. L. BAKER, apparently at the same place, include *Productus*, *Syringothyris*, *Tetracema subtrigona* M. & W., *Spiriferina*, *Reticularia* cf. *pseudolineata* (HALL), *Chonetes*, *Athyris lamellosa* (LEV.), etc., which are definitely Lower Mississippian[1]).

The upper part of the Peregrina Beds may therefore be regarded as Upper Mississippian or Pennsylvanian.

Red Beds (Permian?).

Red Beds have long been known. The writer found them also in the interior ranges of Miquihuana and Aramberri (p. 351). Some geologists have considered them to be Upper Jurassic. According to our observations, however, the Red Beds in the Victoria Range must be older. They consist of: (1) Red clay-shale, more or less sandy, with occasional layers of sandstone and conglomerate; (2) Red conglomerate (15 m thick), well exposed on the road west of Huizachal. On the Peregrina trail it is about 30 m thick and is badly crushed. The pebbles of gneiss and other metamorphic rocks attain the size of one's head. The crushing seems to have developed along the unconformity above the Red Beds, plainly visible west of Peregrina (Pl. XVII, Section 1). The dip is 0—30° higher than in the overlying Novillo Beds (Textfigs. 2c and 3). This unconformity explains the local absence of the conglomerate at El Nacimiento, about a mile east of Peregrina, where the red shale is found in contact with the Novillo Beds, both standing nearly vertically. It also explains the local reduction here of the Red Beds to less than 50 m.

North of Victoria, a thick body of Permian limestone has been described (*Diligenciaschichten*, HAARMANN 1913; HAACK 1914). Apparently this limestone fills the hiatus at the unconformity below or above the conglomerate.

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[1]) G. H. GIRTY also regards the fossiliferous horizon as Mississippian. See MUIR 1936, p. 7-9

Novillo Formation.

Formerly, this division was either regarded as the lower part of the Tamaulipas Limestone or completely ignored, but it is easily distinguished by its peculiar clay-ironstone facies. The name is taken from Novillo Canyon, west of Victoria, where the lower part, in contact with the red conglomerate, is exposed on the trail between the upper and lower ranches of Novillo (Fig. 2 B), as follows:

(c) Fine-grained, sandy limestone, resembling that of the Chicontepec Series	20 m
(b) Dark-bluish, dense to fine-grained limestone, resembling Tamaulipas Limestone	15—20 m
(a) Fine-grained ironstone, in compact beds up to 1 m each	4 m

The weathering is distinctly brownish and different from that of the Tamaulipas Limestone. A more complete exposure occurs on the road east of Huizachal, as follows (Textfig. 3):

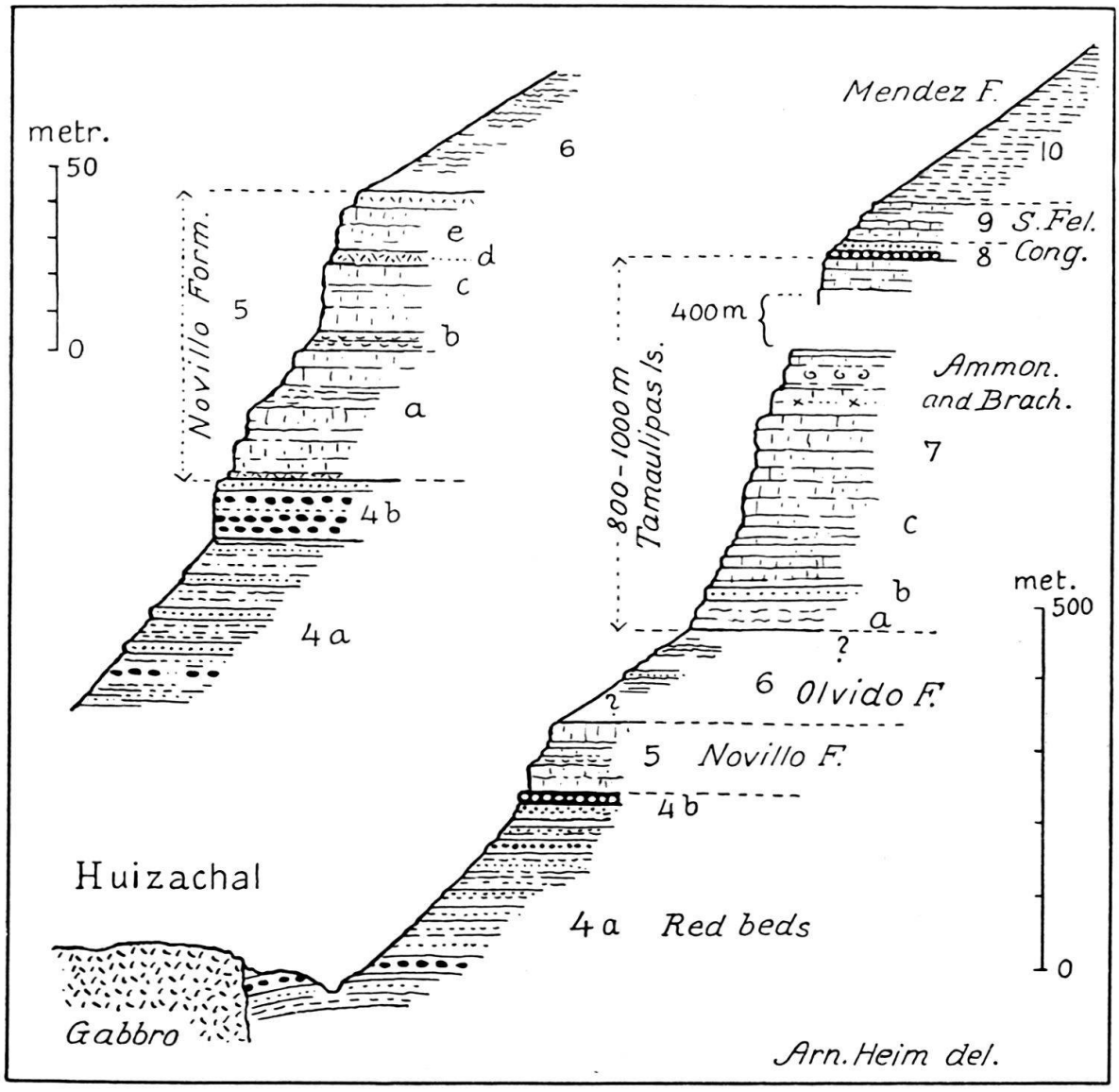

Fig. 3. *Stratigraphic Sections of Huizachal, SW of Ciudad Victoria.*

(e) Limestone and ironstone, like c and d, with grains of glauconite	20 m
(d) Ironstone, weathering brown	4—5 m
(c) Blue, dense to fine-grained limestone with algae	18 m
(b) Thin-bedded limestone with marls, weathering yellow-brown, with abundant *Exogyra* and *Rhynchonella multiformis*	5 m
(a) Dark limestone, weathering light grey, with basal ironstone	35 m

Here the Novillo Beds lie conformably on the Red Beds. A transition-facies a few metres thick, is probably due to reworking of the latter.

As a whole, the Novillo Beds are a distinct lithological unit, 50—100 m thick, of limestones with interbedded ironstone-layers. Fossils are poorly preserved. Dr. C. BURCKHARDT considered the *Rynchonella* to be a Neocomian species, but according to SCHMITTOU (in MUIR 1936, p. 13—14) the Novillo Beds would be Upper Jurassic or even older.

Olvido Formation (" Gypsum Beds").

No upper contact of the Novillo Formation was found. In Peregrina and Novillo Canyons, the Novillo Beds are separated from the Tamaulipas Limestone by a wide slope covered with boulders and " caliche " (surface-breccia), indicating a readily weathered substratum. Only in the Huizachal region have outcrops been found. The road west of Huizachal exposes warped beds of yellow to orange-weathering limestone and dolomite with interbedded green, red and violet clay and some sandstone (Textfig. 3). East of Huizachal, in the wild canyon of the abandoned Olvido Ranch, the variegated clays show fresh exposures with big blocks of gypsum. Thus, the general obscurity of this series at Novillo and Huizachal is explained. It is 50—300 m thick.

The writer nowhere found an exposure of the contact with the overlying Tamabra Limestone. In Peregrina Canyon, the lowest exposures of Tamaulipas Limestone seem to overlie the Gypsum Beds directly. The age is still problematical. Our observations are difficult to correlate with those of SCHMITTOU (in BURCKHARDT 1930 and MUIR 1936). It seems that he underestimated the thickness of our Olvido series, and that he did not separate it properly from the totally different facies of the Novillo Beds[2]).

Portlandian-Valanginian.

In Peregrina Canyon, only isolated outcrops of dense, grey limestones were noted directly under the walls of Tamaulipas Limestone, with patches of yellow, rose and red colour and some brachiopods. Later however, SCHMITTOU seems

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[2]) Compared with MUIR's Fig. 3, p. 14, our main divisions seem to correspond to SCHMITTOU's as follows:

	Rancho Molino	WSW of Huizachal	ESE of Huizachal
Olvido Formation	—	J—G	J—B
Novillo Formation	C	Q—L	O—K

to have found good exposures and the late Dr. BURCKHARDT identified his ammonites (MUIR 1936, p. 13—14, 22). Their result is as follows:

2. Valanginian, WSW of Huizachal: grey limestone alternating with marly chalk, and containing *Astieria schenki* UHL. non OPPEL, *Neocomites* aff. *paraplesius* UHL., *N. neocomiensis* (D'ORB.), and *Polyptychites* . . . . . 10 m

1. Portlandian: marly limestones with shales and dark sandstones, containing *Perisphinctes and Holcostephanus* of the *stephanoides*-group . . . . . 4—6 m

Tamabra Limestone (Lower and Middle Cretaceous).

This important limestone-division was originally called after Tamasopo Canyon, in the Inner Ranges along the Tampico–San Luis Potosí railway. After C. L. BAKER's discovery of a Senonian *Coralliochama* in the type-section, the name Tamasopo could no longer be used for the limestones which underlie the Turonian of the Front Ranges. Three names are introduced for different facies:

(a) Taninul Limestone, from a station on the San Luis Potosí railway in front of the El Abra Range: a reef-type with large rudistids and breccias.

(b) Abra Limestone, from the quarries of El Abra, 2 kms farther east on the same railway: rudistids have given place to miliolinids, which locally make up 50% of the rock (Textfig. 5).

(c) Tamaulipas Limestone, forming a great part of the Sierra de Tamaulipas and the Sierra Madre near Victoria: a well-bedded, dense, black to grey limestone with chert, weathering bluish-white, the beds frequently with stylolith-jointing.

White limestones with chert may be intercalated in the black Tamaulipas or in the Abra facies, and no sharp boundary can be drawn, one type passing into the other. According to H. ADRIAN, the normal Tamaulipas limestone with chert, in the Sierra Tamaulipas, is underlain " by pure white limestone without silex ", which has also been called Tamaulipas.

For the entire limestone-complex beneath the San Felipe or the Xilitla (Agua Nueva) Formations, the writer proposes the name Tamabra Formation, including the different facies.

Near Victoria, the Tamaulipas (Victoria) facies predominates (Pl. XVI). It is well exposed on the road to Huizachal, and is chiefly formed of distinct beds, 10—100 cm thick, of compact, dark and dense limestone with concretions and thin layers of dark chert. In hand-specimens and in the field, the resemblance to the Upper Jurassic *Hochgebirgskalk* or *Quintnerkalk* of the Swiss Alps is striking. The bedding-planes are often very uneven, suggesting submarine solution. Styloliths are common.

At Cumbre, 1200 m above sea-level (Pl. XVII, Section 3), and on the slope towards Huizachal, belemnites (*Belemnopsis minima*?), ammonites and *Terebratula* have been found. The shells have usually been dissolved and so are specifically indeterminable. According to Mr. W. S. ADKINS, they are Vraconnian (Middle Cretaceous) types. Their exact horizon at Cumbre is obscured by complicated folding and crumpling, but they clearly belong to the middle part of the Tamaulipas Limestone (Textfig. 3). This is confirmed on the western limb of the Huizachal Anticline, where ADKINS found the same fossils (*Desmoceras*, belemnites) at similar horizons.

The total thickness of the Tamabra Series at Victoria is about 1000 m (Textfig. 3), almost five times as great as in the Sierra Tamaulipas and at Pánuco (MUIR 1936, p. 37). In the Canyon del Novillo, the lower division forms huge

walls of thick-bedded, white, dense limestone like that of the Sierra Tamaulipas itself. Higher up, the limestone is of Urgonian type (El Abra facies), and contains quartz-grains. Thus, even in this northern region, the Tamaulipas facies is locally mixed with the Abra type. The top of the Series, at Victoria, is a thin-bedded, black limestone, 80—100 m thick (7b in Fig. 2 A). Possibly, this horizon already belongs to the Turonian.

Xilitla (= Agua Nueva) Formation (Turonian).

Before 1925, no distinction was made of strata between the Tamaulipas Limestone and the San Felipe beds. In the region of Victoria, the Xilitla Formation is only locally represented. At the entrance to Novillo Canyon, the following succession is seen (dip 25° ENE):

4. Dense, speckled limestone-beds, weathering yellowish, with *Globigerina* (= San Felipe Beds), passing into
3. Thin-bedded, fine-grained, siliceous limestone with chert (= Xilitla Beds?) . . . . 5 m
2. Massive grey limestone, dense to fine-grained, with big chert concretions (Upper Tamaulipas). . . . . 5 m
1. Thin-bedded, dense, black Tamaulipas limestone.

While marine sedimentation seems to have been continuous near Victoria, conditions were different on the west side of the Huizachal Anticline. At La Mula, the Tamaulipas Limestone is covered by several metres of a coarse conglomerate or breccia with limestone-pebbles, resembling caliche. Above it follow some metres of calcareous sandstone with mica, which passes into the San Felipe series. Thus, west of Huizachal, the Xilitla Beds are lacking or represented by clastic sediments (8 in Textfig. 3).

San Felipe Formation (Coniacian).

The name San Felipe was formerly taken to include the Xilitla. At the type-locality on the San Luis Potosí railway, however, no Xilitla Beds are seen. Hence the writer proposes to use the name in a restricted sense, as has been done by MUIR (1936, p. 58). The formation is easily recognised by the regular inter-stratifications of marl and dense, yellow-weathering limestone-layers and by the lumpy fracture, due to algae *(Fleckenmergel)*. With a lense, foraminifera can usually be observed, especially *Globotruncana* and *Globigerina*.

Typical San Felipe beds are present throughout the Victoria region, where they average from 100 to 200 m in thickness. West of the Huizachal Anticline, the San Felipe beds are only 50—80 m thick, and contain several thin layers of characteristic, intensely green, marine tuff (bentonite). South of Victoria, in the La Prada region, the thickness increases to over 300 m (Fig. 2; Pl. XVII, Sections 3, 4).

Locally, the San Felipe formation is entirely absent. This is the case on the eastern border of the El Abra front range, where the Mendez marls overlie the Tamabra with rudistids directly (Pl. XVII and Textfig. 4).

Wherever the formation is represented, it passes gradually upward into the Mendez Marls. Hence the stratigraphic boundary cannot be mapped properly in areas where the beds lie horizontally. The San Felipe division, as accepted by MUIR (1936, p. 58) is Lower Senonian (Coniacian) in age.

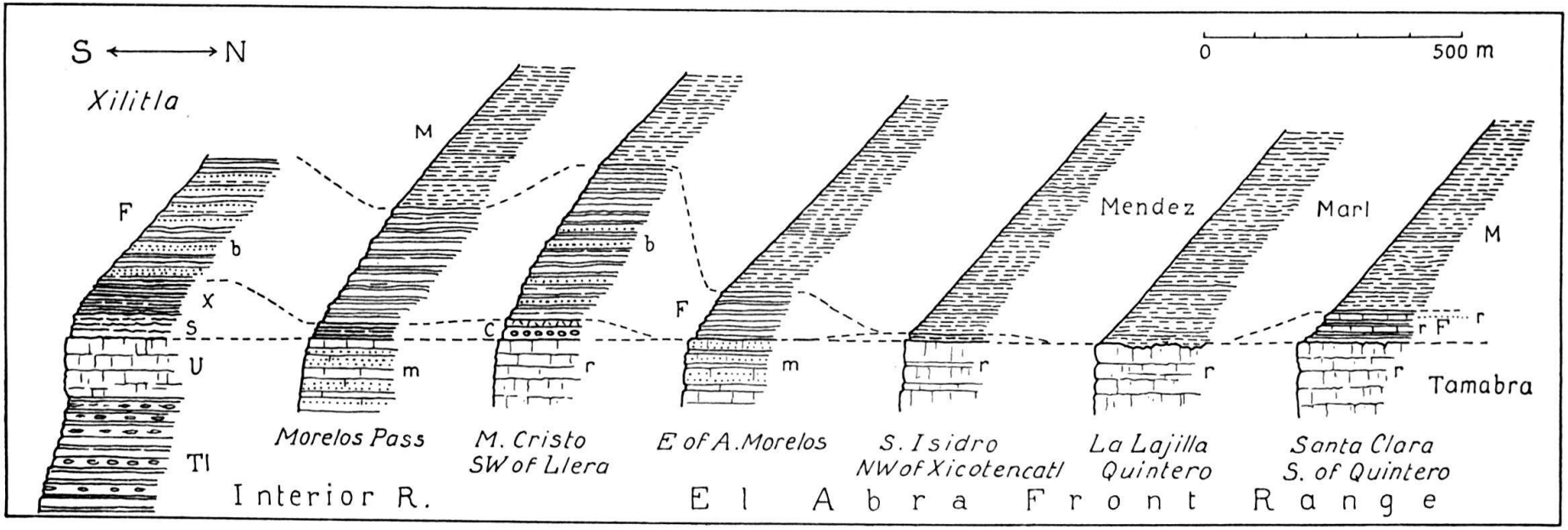

Fig. 4. *Stratigraphic Contacts between Tamabra Limestone and Upper Cretaceous.*

M: Mendez Marls (Middle Senonian);

F: San Felipe Formation; b: layers of bentonite tuff (points); r: limestone with rudistids;

X: Xilitla Formation, bituminous (Turonian); S: black limestone with chert; C: conglomerate and breccia;

Tamabra Formation (Middle Cretaceous): U: Urgonian facies with echinoderm fragments;

Tl: Tamaulipas- or Victoria facies with chert; m: Miliolinids *(Nummuloculina)*; r: Rudistids.

Mendez Marls (Senonian).

The well-known Mendez Marls fill the great synclines of the Victoria and Jaumave valleys and are completely stripped off the flanks of the mountain ranges. They are dark grey to greenish and break up into angular fragments. Where calcareous layers are absent, the stratification is obscure. The resemblance in facies, micro-fauna and age to the *Amdener Mergel* of the Helvetic Alps is striking.

(c) Front Ranges South of Victoria.

Tamabra Limestone.

South of the Rio Guayalejo, the Tamabra constitutes the cores of the anticlinal mountain-ranges (Pl. XVII—XVIII). In the Monte Cristo-Carabanchel region (Pl. XVII, Section 6), it forms an immense anticline reaching an elevation of 2 100 m. At the village of Monte Cristo, the highest beds are full of rudistids. They overlie a massive, dense, white limestone with occasional corals, *Chamidae* and chert-nodules. But on the high plateau, the highest Tamabra consists of about 30 m of this dense limestone, while below are thick beds full of rudistids and *Chamidae*, yielding a strong smell of sulphuretted hydrogen under the hammer. In the narrow anticlines farther west (Sierra Prieto), the dark Victoria-facies with chert is interbedded with white limestone of Urgonian type, containing occasional rudistids and *Chamidae*.

Southwards from Gomez Farias, the eastern border of the Sierra del Abra consists of pure rudistid-limestone in thick, white, cavernous beds, intercalated with coarse breccia and conglomerates of rolled limestone-fragments. This facies extends beyond Taninul to the Rio Tampaon. Over this distance of 125 kms, the rudistid-facies only occurs in the eastern limb of the anticlinal mountain-range with a breadth of 1—3 kms. Westwards, it rapidly passes into the El Abra facies with benthonic foraminifera *(Nummuloculina)* and loses the big rudistids.

This change in facies is well seen between Quintero and Antigua Morelos, and again, 70 kms farther south, along the railway between Taninul station and El Abra (Pl. XVIII, Sect. 10; Textfig. 4). The eastern or main quarry at El Abra (Pl. XVIII, Sect. 13) exposes the upper 50 m of the Tamabra. Several interdigitating facies can be distinguished:

(a) Miliolina-limestone, resembling a white oolite and constituting a perfect " Miliolinite ". Dr. W. LEUPOLD, of the University of Zurich, has kindly studied thin sections and prepared Textfig. 5. According to him, the genus is *Nummuloculina* STEINMANN.

(b) Dense, light-coloured limestone with calcite in veins and patches.

(c) Echinoderm-limestone, of Urgonian type, partly crystalline, resembling the *Schrattenkalk* of the Alps.

(d) Subordinate rudistid-limestone-layers (Taninul facies).

(e) Irregular streaks and patches, a few metres thick, of black, bituminous limestone (recalling the Xilitla facies), 30—40 m below the top of the quarries.

In the next range inwards, that of Chamal, the facies is again mixed. On the trail from Chamal to Ocampo, only the upper Tamabra is visible in the Victoria (Tamaulipas) facies. In the deep cut at La Boquilla, 6 kms to the south, the following types occur in descending order: Tamaulipas; El Abra; Taninul; a chalky granular facies. The last, several hundred metres below the top of the Tamabra at La Cueva (Pl. XVIII, Sect. 9) is characterised locally by remarkable

calcite-poikiloblasts *(Sammelkristalle)*. The rock is porous and cavitous and smells slightly of oil. The resemblance in facies to the Lebanon Limestone of Syria, of the same age, is striking. On the pass between Antiguo and Nuevo Morelos (Textfig. 4), the upper Tamabra is of the mixed type: perfect "miliolinite", black dense Tamaulipas facies with or without *Nummuloculina*, and light grey limestone of Urgonian type with *Chamidae*.

The Sierra Colmena, the next range west of Nuevo Morelos, also shows *miliolina*- and rudistid-limestones. Farther south, miliolinids occur all the way along it to its end at Tanchanaco, and rudistids are seen in many places south of the San Luis Potosí railway. The next Tamabra range still shows miliolinids on its eastern border, in the region between Aquismón and Tocomón.

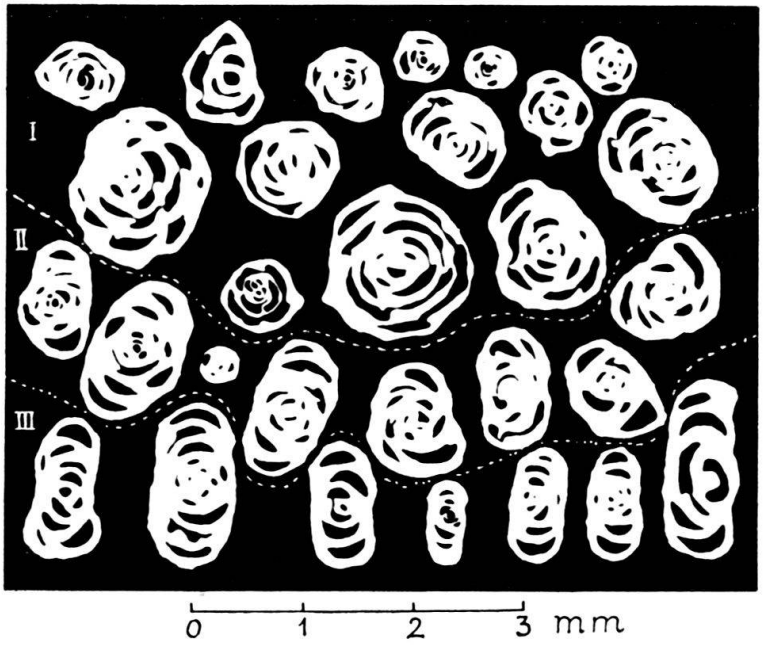

Fig. 5. *Nummuloculina* sp.

Sections through miliolinid-limestone from El Abra:
I, equatorial; II, oblique; III, approximately axial.
From a photograph by Dr. W. Leupold, Zurich.

At Xilitla, the facies rapidly changes. North-west of this town, at Tlamaya, the Xilitla Beds are underlain by a huge mass of typical Taninul Limestone with abundant rudistids, at least 400 m thick. South east of Xilitla (Cruztitla), on the other hand, the Tamabra is made of dense limestone with chert, in well-defined beds with uneven joints (Tamaulipas type). It is several hundred metres thick and thrust over true San Felipe Beds east of Xilitla. Above it comes El Abra Limestone of massive Urgonian type, with chert. Thickness 100—200 m. In places, black bituminous shale is interbedded and resembles the lower part of the Xilitla Beds.

Thus the Tamaulipas, Taninul and El Abra Limestones are different facies of the same Tamabra Formation, interdigitating laterally and often repeated above one another at the same locality (mixed-facies). In addition to

the five types of facies described from the quarries at El Abra (p. 324), we have to add:

(f) Tamaulipas or Victoria facies, dark, dense limestone,

(g) Chalky or granular, microcrystalline type (Boquilla, Micos Canyon, parts of the Pánuco oil-fields), with or without calcite crystals.

In the Inner-Ranges, west of Jaumave (p. 349) we have found:

(h) Limestone resembling an algal breccia,

(i) Oolitic limestones.

Apart from such irregular changes the main types are distributed as follows:

1. The Tamaulipas type predominates in the northern region of Victoria, but reappears to the south of Xilitla below the Abra type.

2. The border of the Front Range, for 125 kms between Gomez Farias and the Rio Tampaon, is represented entirely by the Taninul facies with rudistids.

3. This sub-reef type passes westward in 1—2 kms into the El Abra type, with miliolinids. These benthonic foraminifera, when developed abundantly, seem to be restricted to the upper 200 m of the Tamabra.

The thickness of the Tamabra, as a whole, seems to diminish to the south, from 1000 m to a few hundred metres at Tamazunchale.

Xilitla (Agua Nueva) Formation[3]).

The contact of the Tamabra with the Upper Cretaceous is very variable, the Xilitla Beds being locally absent or replaced by conglomerate and breccia. But as a whole, " by both lithology and fossils this horizon is easily identified all over northern and central Mexico " (BÖSE & CAVINS 1927, p. 67). The typical Xilitla Beds are black to brown, flaggy shales or siliceous limestones, weathering light brown to pink, with a bituminous smell or even liquid oil, and containing numerous ganoid-scales. It is a true source-rock, though not of great commercial importance. Like the Californian Monterey Shales (ARN. HEIM 1924), the Xilitla Beds are thought to be a coldwater, marine deposit. On the map, the formation is shown with a special colour where distinctly differentiated and widely distributed; elsewhere it is indicated with a black line or included with the San Felipe. Frequently, the outcrops are lacking.

Between Monte Cristo and La Libertad, the horizon is represented by conglomerates and breccia (Textfig. 4). An outcrop south of Monte Cristo village (Pl. XVI, Sect. 6) shows:

3. San Felipe Beds:

(c) Dense *Fleckenmergel* and yellow-weathered, sandy limestones containing beds of green sandstone,

(b) Blue limestone-breccia, cemented with limestone and containing chert. . . 3—4 m

(a) *Fleckenmergel*, limestones and sandstones, like (c) . . . . . 15—20 m

2. Xilitla Breccia- Series:

(e) Conglomerate-breccia, resembling " caliche ", with large limestone-fragments and shell-fragments. . . . . 2—4 m

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[3]) The name Xilitla Flags was introduced by W. S. ADKINS in a report for the Shell Group and treated as a separate formation in my report of 1925 (see also ARN. HEIM 1926, p. 87). Subsequently, it was called after the Agua Nueva locality, in the Sierra Tamaulipas, by L. W. STEPHENSON (MUIR 1936, p. 44). Priority apart, no better name can be found for a type-locality than Xilitla; this little town stands on well-developed, typical Xilitla Flags, of which it is built.

(d) Black limestone of Tamaulipas facies with big chert-concretions at the top 6—8 m
(c) Dark, dense limestone, resembling Tamaulipas facies . . . . . 5—10 m
(b) Massive, rough limestone-breccia, cemented with dense limestone . . . . . 10 m
(a) Dense, light-grey limestone (Top of Tamabra?) . . . . . 4 m

1. Tamabra Limestone with rudistids (Taninul facies).

Similar conglomerates were noted at La Libertad. On the Rio Sabinas, south of San Isidro ranch, is exposed a fine-grained, thin-bedded, dark-grey, impure limestone with fragments of echinoderms. Similar traces of the Xilitla Formation occur near Gomez Farias. Farther south, along the eastern border of the Front Range, the Xilitla and San Felipe beds are completely absent. Only at Salsipuedes, on the southern end of the El Abra front range, do typical Xilitla Flags recur.

In the second range, the Sierra Romana, the Xilitla Beds are well represented. They pass upwards into the San Felipe, but the lower contact with the Tamabra is well-marked. In the Chamal-Morelos region they are 20—40 m thick. The best outcrop is on Morelos Pass, between Antiguo Morelos and Nuevo Morelos (Textfig. 4; Pl. XVIII, Sect. 10). There is a sharp contact between Xilitla- and Abra Limestone with miliolinids. The Xilitla weathers in thin layers, recalling the Monterey Shale of California. It is crowded with fish-scales and smells bituminously, although no soluble oil could be extracted with chloroform. The lower part is thin-bedded (layers 5—30 cms thick); the upper part is more thickly-bedded and passes into San Felipe limestone with *Globigerina* and *Globotruncana linnei* (D'ORB.). The Xilitla extends eastwards to the west limb of the El Abra Range, where it dies out between the Abra Limestone and the San Felipe Beds. Similar conditions occur farther south.

In the third range, the Sierra Colmena, the Xilitla Formation is exposed near Micos Falls, on the railway SE of Micos (Pl. XVIII, Sect. 12) and again farther south at Jopoy. Still farther south, at La Pila, the Xilitla Formation is absent, dying out with the San Felipe towards the Rio Tampaon. But it reappears in its greatest development in the regions of Tanchanaco and Xilitla, where the beds have seepages of oil and tar.

The town Xilitla stands at 570 m on the top of the middle part of the Xilitla Series which dips 20—25° NE. A quarry north-west of the town furnishes paving- and building-stones. Large impressions of fishes are seen on the pavements of the roads. BÖSE (1913, p. 26) cites *Inoceramus labiatus* SCHLOTH., a Turonian species, and C. L. BAKER further mentions *I. hercynicus* PET. and *Acanthoceras*. The following section was compiled from outcrops north-west of Xilitla (Textfig. 4; Pl. XVIII, Sect. 16):

3. San Felipe Beds, unusually rich in green, argillaceous and tuffaceous beds (bentonite) . . . . . 200—300 m
2. Xilitla Formation . . . . . 100—150 m
(d) Black limestone beds, 10—30 cms thick, interbedded with shale and chert-layers and some bentonite . . . . . 30 m
(c) Shaly flags with streaks of green bentonite . . . . . 15 m
(b) Xilitla Flags: black, bituminous and thin-bedded, with thin chert-layers, fish-bones and scales and *Inoceramus labiatus* SCHLOTH. (Turonian), . 20 m
(a) Black limestone with big chert-concretions, resembling Tamaulipas facies, in thick, nodular, uneven beds, 1—2 m thick, and limestone-breccia with occasional glauconite-grains (? Tamabra, Cenomanian ?) . . . . . 50—80 m

— Sharp Contact —

1. Abra Limestone, massive, white and microcrystalline, with broken shells.

The upward passage into the San Felipe series is indicated by limestone-layers of San Felipe type with Globigerina in beds 2 (d) and by the occurrence of black layers at the base of 3[4]).

The bituminous layers, 2 (b), (c), resemble the Menilite Shales (BLUMER 1922, p. 112) in the Oligocene of the Carpathian oil-fields.

San Felipe Formation.

The San Felipe series is of secondary importance in the mountain-ranges. Throughout the Front Ranges, it passes directly into the overlying Mendez Marls. Its lower limit, however, is very variable and frequently shows a distinct unconformity (Textfig. 4). In places, the Mendez overlaps on to the Tamabra.

The thickness of the San Felipe at Llera–La Prada is 200—400 m, at Monte Cristo 200 m. In the latter region, the lower subdivision has thick beds of hard, greenish sandstone and tufflayers. At Fortunas ranch on the south end of Sierra Prieto (Pl. XVII), typical San Felipe limestones are still more than 200 m thick, but they diminish rapidly to the south-west and die out a few kilometres south of La Libertad. They are entirely absent along the eastern border of the Front Range but are constantly present in the second and third ranges. Where only gently folded, they may cover large areas, e. g., at Chamal, south of Antiguo Morelos and in the type-area of San Felipe, east of Valles, where the thickness is 200—300 m (Pl. XVI; Pl. XVIII, Sections 10—13).

Returning to the eastern border of the Sierra del Abra, we find the San Felipe Formation setting in again at Santa Clara, south of Quintero, but with a suprising change of facies. It includes several beds of coarse breccia and rudistid-limestone, ½—1 m thick, indistinguishable from the Taninul facies of the Tamabra (Textfig. 4). Dense red limestone with *Globigerina* is also interbedded, recalling the *Couches rouges* of the Alps (ALB. HEIM 1919—22, pp. 626—628), and whitish to greenish tuff (bentonite). Otherwise, the San Felipe is easily recognisable by its repetitions of marls and dense *Fleckenkalk*, although it is only 30—50 m thick. These observations were confirmed farther south, at El Choy, by Dr. FEHR. Still farther south, along the eastern border of the Sierra del Abra, the San Felipe beds again disappear and are entirely absent at Taninul.

The eastern limit of the San Felipe is a line coming from the north-east passing south of Llera to La Libertad, then turning southwards and following the crest of the Front Range for 70 kms. South of Quintero, the boundary undulates slightly along the eastern border of the Front Range, continuing southwards to Tampaon. East of this line, however, the San Felipe is again found in the plain, where it comes to the surface in small domes and anticlines (Pl. XVI). Drilling showed that it is well represented in the San Pedro Valley (Pl. XVIII, Sect. 15). Thus the San Felipe is absent along a narrow strip trending N–S along the Front Range.

Returning to the inner ranges, we find a similar dying-out south of La Pila. No exposure of the San Felipe–Tamabra contact was found. But at Urraca and on the Rio Tampaon, where the San Felipe must be considerably reduced, at least, not even boulders could be found on the slope. At the southern end of the

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[4]) MUIR (1936, p. 60) says: " Southeast of Xilitla the Turonian (Agua Nueva) overlies Albian-Cenomanian rocks, and is itself overlain by the Tamasopo limestone ". This ought to oead: " South-west of Xilitla the Turonian is overlain by a thick mass of San Felipe rocks, rver which lies the Tamasopo Limestone ".

Sierra Colmena (Tanchanaco), and throughout the Sierra de Aquismón to Xilitla and Tamazunchale, the San Felipe is present, but in restricted thickness. A special facies at Xilitla is characterised by an abundance of green bentonite.

Mendez Marls.

In the region of Xicotencatl, east of the Front Ranges, the wide-spread Mendez Marls may be subdivided into:

2. Dark, greenish marls with cleavage and obscure bedding, many hundred metres thick.
1. Well-bedded, bluish-grey marls with occasional thin layers of limestone, 200—300 m.

The Mendez is purely marine and contains numerous microforaminifera. Two special facies have been observed:

(a) White layers of tuff in the middle Mendez at Buena Vista and Cerrito, NW of Xicotencatl. At Las Animas and Caimán, in the Antiguo Morelos Syncline, these are very hard and tough, forming well-defined beds, each 2 m thick and 25 m thick in all. They form broad mesas, several sq. kms in area and dip 0—5° E (Pl. XVI).

(b) South of the Rio Tampaon, a red variety of Mendez Marls occurs, especially in the middle and upper parts of the series, resembling the reddish shale of the type-locality on the railway from Tampico to Valles (Muir 1936, p. 69). The northernmost exposure of red shale was found at Paliguau. At San Pedro, in the creek near La Labor well, the shale is partly blood-red, partly violet, greenish and yellowish. The best exposure of red Mendez beds is along the trail east of Cerro Guajolote, between Aquismón and Tancanhuitz.

With increasing colour, the Mendez develops sandy and indurated horizons. This is the case between Huichihuayan and Matlapa, NW of Tamazunchale. It is often difficult to distinguish this facies of Mendez from the overlying Tamesí beds.

The total thickness of the Mendez could not be measured in the northern region on account of interrupted outcrops and obscure stratification. It is believed to be about 1000 m (part of the Tamesí possibly included).

In the south, definite data are obtained from drilling at San Pedro. Well No. 1 commenced in the upper part, reaching the San Felipe at 3650 ft. The total thickness is thus about 1300 m. The only question is whether the uppermost part should not be regarded as Tamesí. Farther south-west, towards Tocomón and Tamazunchale, the Mendez Series thins by more than half.

The age of the Mendez is Santonian-Campanian (Middle Senonian). A great number of foraminifera have been determined recently by different specialists (see Muir 1936, pp. 69, 73).

Tamesí Formation.

In my 1925 report I termed Barrancón Beds the series overlying the Mendez in the San Pedro Valley and vicinity, from the fine outcrop at El Barrancón from which J. B. Dorr has recently determined 82 species of foraminifera (Muir 1936, p. 86—88). The name Tamesí having been agreed upon by Tampico geologists, the name Barrancón, as a formation, can be dropped (Muir 1936, p. 78). In former reports the Tamesí was grouped either with the underlying Mendez or with the overlying Chicontepec. Our mapping establishes its wide distribution and individuality.

In the north the Tamesí has been observed:

1. About 2 kms NE of Llera, as a greenish shale resembling a special facies of the Mendez, but interbedded with ripple-marked, sandy flags (Pl. XVII, Sect. 5).

2. In the bed of the Rio Guayalejo at Xicotencatl (Pl. XVII, Sect. 7), where shale of Mendez type is interbedded regularly with calcareous sandstone in beds 1—20 cms thick. Farther south, the Tamesí also occurs below the great plain.

At El Barrancón (San Pedro Valley), the creek has cut a high bank, the lower part of which consists of blue-grey marls with extremely thin, nodular layers of calcareous, micaceous sandstone at intervals of about 20 cms. They are full of tracks of animals resembling *Helminthoides* and plant-fragments. This series, of which about 50 m are exposed, dips 10° SW and is overlain by calcareous sandstone of the Tanlajás Series (Lower Chicontepec). Another excellent exposure, in steeply upturned strata, showing the full thickness, is seen along the trail north of Tancanhuitz, at La Cuesta. The Tamesí beds give place abruptly to the overlying Tanlajás sandy limestone. The Tamesí Formation was mapped continuously from San Pedro round the Chicontepec Mountains, by Tancolol and Tancanhuitz down to Tamazunchale. The thickness averages 100—200 m (Plate XVI).

From the foraminifera, the age is considered to be Upper Senonian-Danian.

Tanlajás Series (Lower Chicontepec).

The Chicontepec, generally regarded as Lower Eocene, is about 2000 m thick and is subdivided into:

3. Upper Chicontepec or Jaco Sandstone
2. Middle Chicontepec or Chalma Shale
1. Lower Chicontepec or Tanlajás Sandstone.

Again commencing in the north: From Lavin station, south-east of Victoria, along the railway down to San Francisco, Forlon, Xicotencatl and beyond to Magiscatzin and El Naranjo, the wide synclinal plain consists of gently undulating Tanlajás Beds and is covered with slabs of calcareous sandstone, 5—30 cm thick, with uneven surfaces and weathering brown, like basalt. They are equivalent to the Tanlajás of the San Pedro Valley.

The most interesting outcrops are found east of Magiscatzin, north-west of the imposing volcanic plug of the Bernal de Horcasitas, 1111 m high (Arn. Heim 1934). The unfossiliferous slabs dip gently east. Two km from the abandoned ranch of San Juan, blocks of rough sandy limestone and *lumachelle* contain abundant *Serpula*, brachiopods, single corals, bryozoa, shark-teeth and a small *Nummulina* (2—3 mm in diameter, with central pillar). An extraordinary aspect is given to this rock by huge calcite-poikiloblasts, enclosing grains and fossils (*Sammelkristalle*).

In the San Pedro district, the Chicontepec Formation is well-known and was not studied systematically by the writer. The lower part of the Tanlajás Sandstone is fine-grained and unfossiliferous. Coarse-grained calcareous sandstone with small nummulites occurs 100—200 m above the Tamesí Beds. These sandstones also contain a *Discocyclina* and occasional glauconite-grains. In the creek at Tanlajás, marls are interbedded with the sandstone, which here includes pebbles of ironstone, apparently derived from the Novillo Formation, and of limestone with algae resembling *Lithothamnium*. Between San Antonio and Tancanhuitz,

the upper part of the Tanlajás Series contains interbedded layers of dense, yellow-weathering dolomite.

The Tanlajás Series may be 1000 m thick or more.

Chalma Shale (Middle Chicontepec).

On the north side of the Bernal de Horcasitas and in the Axtla region, the Tanlajás Sandstone seems to be overlain by a grey to greenish sandy shale, somewhat resembling the Tamesí. It probably corresponds to the Chalma Shale (Plate XVI). No Upper Chicontepec Beds are known in the region.

Quintero Limestone.

South-east of Quintero, outside the El Abra Range, lies the conical, flat-topped Cerrito del Campo Santo, reaching an elevation of 170 m. The top is formed of a yellowish limestone with approximately horizontal bedding, about 40 m thick. The texture is dense but cavernous, and the general appearance that of a fresh-water limestone, possibly of Upper Tertiary age. Nothing similar is known in other parts of the Front Ranges. On the map (Plate XVI) it is indicated as *ls* with horizontal hatching.

Caliche (Recent).

This is a surface-conglomerate or breccia, cemented with lime into a hard pan and is distributed especially in the semi-arid region around Victoria. The same type is found in North Africa, wherever the soil contains sufficient lime for cementation. Sometimes it is so hard that it covers the subjacent formations like a coat of mail.

(d) Cretaceous of the Inner Ranges.

The type-locality of the Tamasopo Limestone is Tamasopo Canyon on the San Luis Potosí Railway, 45 km due west of Valles. The sharply-folded limestones are over 1000 and probably nearly 2000 m thick. They are dense, light-coloured, thick-bedded limestones with interbedded argillaceous layers. Occasional rudistids occur, including a Senonian *Coralliochama*, discovered by Mr. C. L. Baker. Eastwards the limestone extends to the longitudinal valley of the Rio Frio (Rio Gallinas), whose east side shows anticlines overturned eastwards in Tamabra, covered normally by Xilitla and San Felipe Beds.

Is this sudden change of facies due to a regional overthrust of the Tamasopo Limestone to the east? On the east side of the valley, at Ingenio Rascón, the Xilitla Formation consists of white, dense limestone resembling the Tamasopo. It seems that a change in facies occurs rapidly, but not abruptly, so that there may not be a regional thrust here.

But at Xilitla an overthrust is hardly disputable. At the same time the stratigraphic relations seen at Ingenio Rascón are confirmed; within the thrust series, a transition occurs from Lower Xilitla (black limestone) to the overlying white Tamasopo Limestone, which forms the peaks of the Sierra de Xilitla (Pl. XVIII, Sect. 16). At Miramar, 1200 m, above Xilitla, Dr. Jenny noted typical San Felipe limestones *(Fleckenkalk)* within the main body of the Tamasopo limestone, 200—300 m above the base of the Xilitla Series. These facts confirm

the paleontological conclusions of BÖSE, BAKER, ADKINS and others, obtained at Tamasopo Canyon in 1923/24, that the Tamasopo Limestone represents the upper part of the Xilitla Beds and the entire San Felipe Formation, possibly including part of the Mendez. It thus belongs chiefly to the Lower Senonian. The Tamasopo Limestone of the Sierra de Xilitla is quite typical. At the base of the Peña de San Antonio, chert-nodules occur which are usually absent higher in the series.

At the western end of Tamasopo Canyon, the Tamasopo Limestone is overlain by a thin conglomerate-bed, followed by 200—300 m of Mendez Beds, which are succeeded by the thick series of the Cárdenas Beds (BÖSE, 1906 A). These are well exposed along the railway, where the following approximate section was observed from Cárdenas eastwards to Escontria (Textfig. 6):

Upper Cárdenas Beds, 2000 m:

13. Yellow limestone, interbedded with marls.
12. Greenish marls, resembling Mendez Beds, 500 m.
11. Sandstone and sandy-marly limestone with oyster-beds: *Gryphaea vesicularis* LAM., *G. costata* SAY, *Ostrea gigantica*.
10. Well-bedded limestone with marls.

(The relations of the above beds to the underlying strata are obscured by folding and lack of exposures.)

9b. Cárdenas Red Clay, several hundred metres.
9a. Red and green clay-shale, resembling Tamesí Beds.

Lower Cárdenas Beds, about 1300 m:

8. Very fossiliferous marls and sandstones with corals, *Coralliochama g.-boehmi* BÖSE, *Exogyra costata* SAY, etc.
7. Hard grey, calcareous sandstone with gastropods: *Conus*, *Turritella*, etc.
(Gap, covered by caliche.)
6. Marls and nodular limestones full of oysters; *Gryphaea*.
5. Grey shale with limestone, 200—300 m.
4. Marls and nodular limestones full of oysters, *Cardium*, *Pholas*, etc.
3. Grey shale with beds up to 1 m thick of yellow limestone full of *Pseudorbitoides*, 100—200 m.

Mendez Marls:

2. Grey, more or less sandy shale, 200—300 m.
1. Conglomerate, 1 m.

Tamasopo Limestone.

Thus the Cárdenas Beds, Upper Senonian in age, represent a shallow-water-facies of the Upper Mendez of the Front Ranges. They are confined to the Inner Ranges, where they were observed as far north as Tula, west of Carabanchel.

(e) The Jurassic of Tamazunchale.

In the south, the Jurassic is well-developed and subdivided into fossiliferous formations from Lias to Upper Jurassic. MUIR (1936, pp. 9—11) gives full details of the Lias. So far as studied by me, only Upper Jurassic is present in the gorges of the Rio Moctezuma above Tamazunchale. Part of the results having been already published (ARN. HEIM 1926), a short resume will suffice.

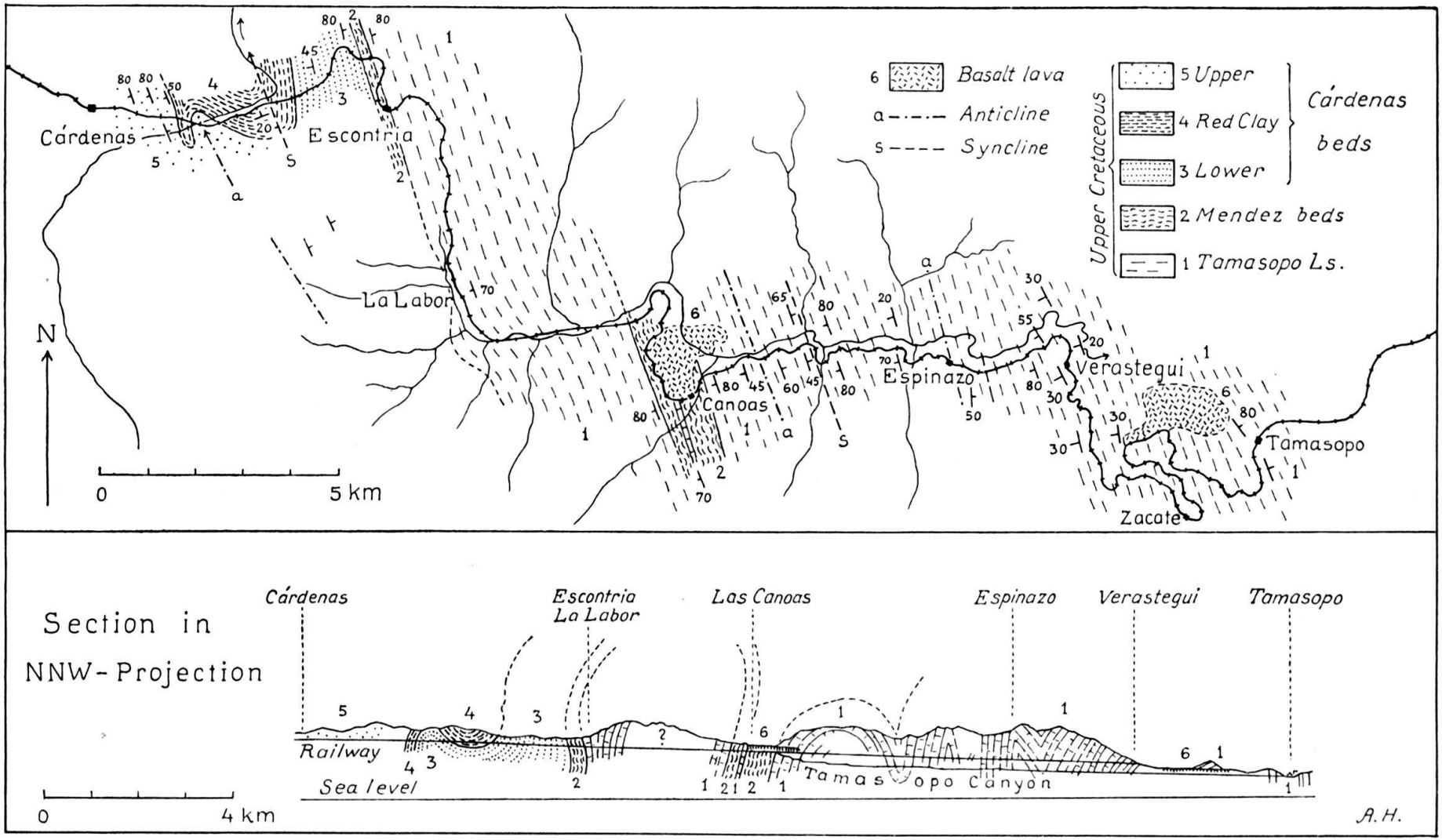

Fig. 6. *Section of Tamosopo Canyon along the Railroad.*

Tamán Formation.

Well-bedded, black, fine-grained and microcrystalline limestones, alternating with black shales and forming an anticlinorium in the centre of which is the village of Tamán. For nearly 10 km the river flows through this series of over 1000 m thickness. The fossils were determined by the late Dr. C. BURCKHARDT as Upper Kimeridgian: *Haploceras fialar* (OPP.), *H. transatlanticum* BURCKH., *Perisphinctes cyclodorsatus* MOESCH in FONTANNES, *Aspidoceras* of the *longispinum*-group, *A.* cf. *polysacrum* FONT., *A. eligmoptychum* FONT., and abundant *Aulacomyella lata* sp. nov. and *A. heimi* BURCKH.

Pimienta Series.

The Tamán Beds seem to pass upwards into a series of black or black and white, thin-bedded, dense limestones with many layers of black chert, 100—200 m. thick. The age is supposed to be Portlandian.

Tenestipa Limestone.

White, dense, massive limestone with chert, about 100—200 m thick, at the village of Tenestipa, and several hundred metres thick at Pimienta, on the opposite side of the great anticline. The relation of this limestone, which may be Cretaceous, to the overlying Upper Cretaceous of the Xilitla region could not be studied. Possibly, the Tenestipa Limestone is a facies of Tamabra.

III. Igneous Rocks.

Igneous extrusions and intrusions took place in Eastern Mexico at various dates (see MUIR 1936, W. STAUB 1922, 1937, 1939). The following types were found in the region mapped, or its immediate surroundings:

1. Granite and basic intrusions, more or less metamorphosed, in Novillo and Peregrina Canyons: Pre-Mississipian.
2. Gabbro, serpentine, diabase, etc., intruded into the Red Beds at Huizachal and Novillo Canyon (Textfigs. 2, 3; Pl. XVII, Sections 2, 3): Pre-Cretaceous, probably pre-Jurassic.
3. Green tuffs (bentonite), interstratified with the Xilitla- and San Felipe Formations: Turonian to Coniacian.
4. White tuffs in the Mendez Marls: Upper Senonian.
5. Basic necks or cones at widely separated localities:

(a) Bernal de la Purisma, 400 m high, overlooking the mesa of that name (Pl. XVII, Sect. 5).

(b) Bernal de la Clementina, at the village of that name, south of the Rio Guayalejo.

(c) Bernal de Horcasitas, 1111 m, SE of Magiscatzin, visible on a clear day from Tampico, 100 km away. A basalt column 1 km thick and 600 m high, rising above a flat, basaltic lava-shield of Hawaiian type, 6—8 km in diameter (ARN. HEIM 1934).

(d) Cerros Morcielago and Nopal, north of the San Luis Potosí railway and 30—37 km NW of Guerrero (Pl. XVI), connected with basalt dykes and lava-flows.