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The Francisco Formation and an Oxfordian ammonite faunule from the Artemisa Formation, Sierra del Rosario, western Cuba

ABSTRACT: The Francisco Formation of Oxfordian age is proposed for the strata separating the San Cayetano and the Artemisa Fm. in the Sierra del Rosario, western Cuba. Moreover, an Oxfordian ammonite faunule with *Mirosphinctes* Schindewolf, and *Cubaspidoceras* Myczyński is described from the basal part of the Artemisa Formation. The stratigraphy of the Jurassic sediments from the Sierra del Rosario is briefly discussed on the basis of the new data. There appears to be a sedimentary continuity from the (?) Lower/Middle Jurassic–Oxfordian San Cayetano Fm. through the Oxfordian Francisco Fm. to the Oxfordian-Lower Cretaceous Artemisa Fm. which indicates that this area has not been affected by the Nevadan orogeny. From the new stratigraphic correlations of the Jurassic formations of the Sierra del Rosario and the Sierra de los Organos it follows that the lithology of isochroneous sediments of these regions is markedly less contrasted than it was hitherto assumed.

INTRODUCTION

Several new data concerning litho- and biostratigraphy of the Oxfordian of the Sierra del Rosario were gathered by a Polish-Cuban team in the course of geological mapping of the Pinar del Río province. In Jurassic sediments hitherto considered as unfossiliferous and of either pre-Oxfordian or post-Oxfordian age, ammonites indicative of the Oxfordian were found at four different stratigraphic levels (*cf.* Myczyński 1976, Myczyński & Pszczółkowski 1976, Wierzbowski 1976).

The part of this paper dealing with the Francisco Formation was written by A. Pszczółkowski, who is the only author of that lithostratigraphic unit. Lithological description of ammonite-bearing basal beds of the Artemisa Formation was also written by A. Pszczółkowski, whereas J. Kutek and A. Wierzbowski are responsible for paleontological and biostratigraphical parts of the paper. All the authors are responsible for the general conclusions.

Acknowledgements. Thanks are due to the Directors and staff of the Instituto de Geología y Paleontología, Academia de Ciencias de Cuba, in La Habana, for the loan of specimens from the collections of the Institute and help in field studies. Thanks are also due to Dr. R. Myczyński for making available the manuscript of his paper (Myczyński 1976), and to J. Dzik, M. Sc., for drawings of the ammonites.

FRANCISCO FORMATION (NEW FORMATION)

This new formation comprises sediments separating those assigned to the San Cayetano Fm. and the Artemisa Fm. in the Sierra del Rosario; up to the present they were not differentiated as a formal lithostratigraphic unit. The name of the new formation is taken after the highlands *Altos de San Francisco* in the central part of the Sierra del Rosario, Pinar del Río province (Text-figs 1 and 2). The formation is represented by argillaceous and silty shales, limestones and sandstones. The shales are dark-grey to black when fresh, becoming grey-brown when wheathered; they often yield calcareous concretions and thin intercalations of marly and micritic limestones. Quartz and polymictic sandstones commonly occur in single layers intercalating shales or limestones and, sometimes, in sets a few meters thick, which occur only in some exposures in lower part of the formation.

The sediments assigned to the Francisco Formation were previously ascribed to the San Cayetano Formation (Herrera 1961, Pszczółkowski

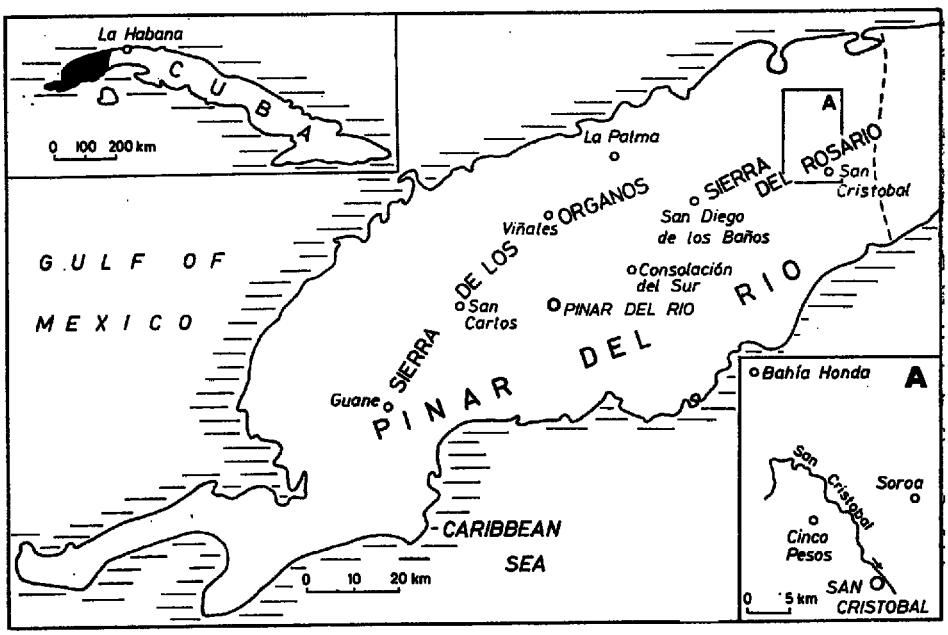

Fig. 1. The investigated area (rectangled; magnified in Fig. 1A) of the Pinar del Rio province (inset shows its position in Cuba)

1971). Shales from the Cinco Pesos area were formerly interpreted as the beds transitional between the San Cayetano Fm. and Artemisa Fm. (Pszczółkowski 1971).

The sedimentary rocks of the Francisco Formation are usually strongly tectonized as they are less competent than the thick limestone sequence of the overlying Artemisa Fm. The Francisco Formation is usually poorly exposed and there is no complete section of that lithostratigraphic unit. The exposures in the Cinco Pesos area, 10 km NW of San Cristobal (Text-fig. 2; localities No. *1* and *2*), are chosen as the type sections of the Francisco Formation.

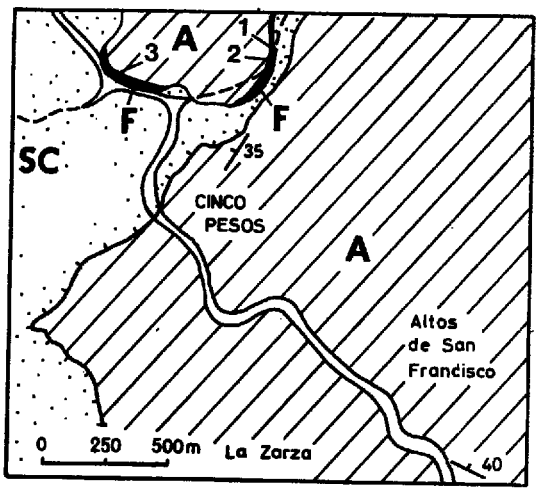

Fig. 2
Geological map of the Cinco Pesos area (*cf.* Text-fig. 1*A*), showing the investigated localities No. *1—3*
SC San Cayetano Fm., *F* Francisco Fm., *A* Artemisa Fm.

Locality No. 1 is situated 20 m N of a subordinary road running E of the main road from San Cristobal to Bahía Honda towards the San Cristobal river (cf. Text-fig. 2; coordinates 282.650 and 328.750). Here are exposed dark-grey argillaceous shales with calcareous concretions dark-grey to black on fresh surfaces and up to 20 cm in size. The concretions yield sparse pelecypods and plant remains. The shales are heavily tectonized and their thickness may be roughly estimated as about 3 m. The contact of the shales with over- and underlying strata is not visible here.

Locality No. *2* (Text-fig. 2) is situated at the northern escarpment of the road to the San Cristobal river (coordinates 282.550 and 328.650). In its eastern part there are exposed a few sets of different lithology (Text-figs 3—4). The lowermost set comprises dark-grey micritic limestones sometimes with horizontal lamination and thin intercalations of argillaceous and marly shales. When hammering they split into thin plates with surfaces covered with plant and sometimes fish remains. The limestones are 5 m thick, and their contact with older strata is obscure but it follows from their geological setting that they overlay the above described concretions-bearing shales cropping out in locality No. *1*. The limestones are overlied by a set of sandstones brown in colour when weathered and with shaly intercalations, 2 m in thickness. The sandstones and shales are rich in plant remains. Higher up there occurs a set of argillaceous and silty shales with thin intercalations of marly limestones. The shales are brown when weathered and they sometimes yield plant remains, pelecypod shell fragments (Ostreidae) and occasional aptychi.

Unidentifiable ammonite fragments were found in marly limestone intercalations a few cm thick. The shales are 3 m thick.

The contact between the shales of the Francisco Fm. and the overlying limestones of the Artemisa Formation is well-displayed by that exposure (Text-fig. 4). Above the shaly set there occur two layers of micritic, somewhat marly limestones, a few cm in thickness and separated by a thin layer of marly shale (Text-fig. 3). The limestone layers yield ammonites. The base of the lower limestone layer is regarded as the boundary between the Francisco Fm. and the Artemisa Fm. This

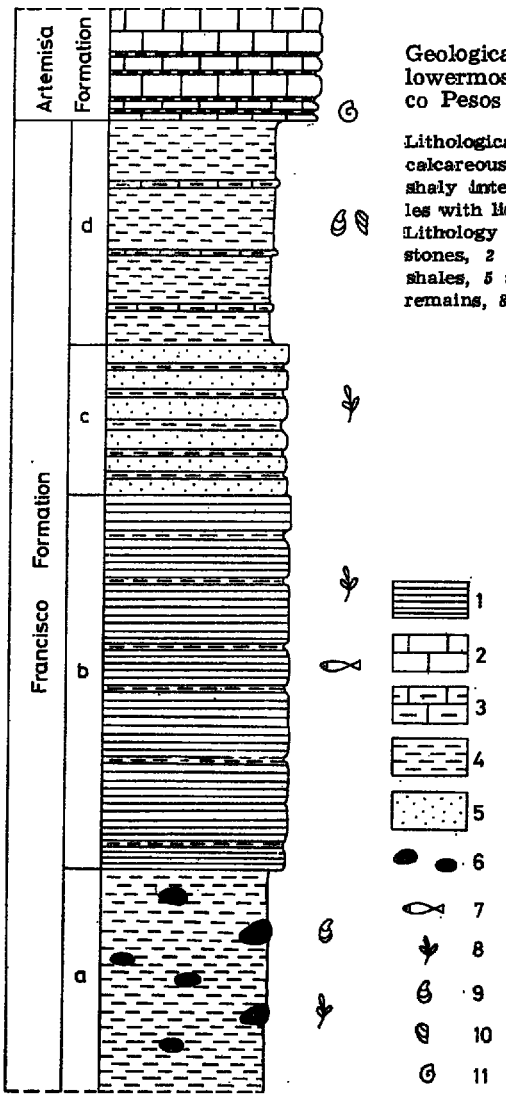

Fig. 3

Geological section of the Francisco Fm. and the lowermost part of the Artemisa Fm. in the Cinco Pesos area (*cf.* Text-figs 1*A* and 2), exposed at localities No. *1* and *2*;

Lithological sets of the Francisco Fm.: *a* shales with calcareous concretions, *b* laminated limestones with shaly intercalations, *c* sandstones and shales, *d* shales with limestone intercalations.

Lithology and organic components: *1* laminated limestones, *2* micritic limestones, *3* marly limestones, *4* shales, *5* sandstones, *6* calcareous concretions, *7* fish remains, *8* plant remains, *9* pelecypods, *10* aptychi, *11* ammonites

Scale 1 : 100

boundary is less clear in western part of the exposure because of local tectonic displacement between the two formations. The ammonite-bearing layers are overlain by a sequence of micritic limestones, over 12 m thick, with thin shaly intercalations in the lower part. All these limestones belong to the Artemisa Formation.

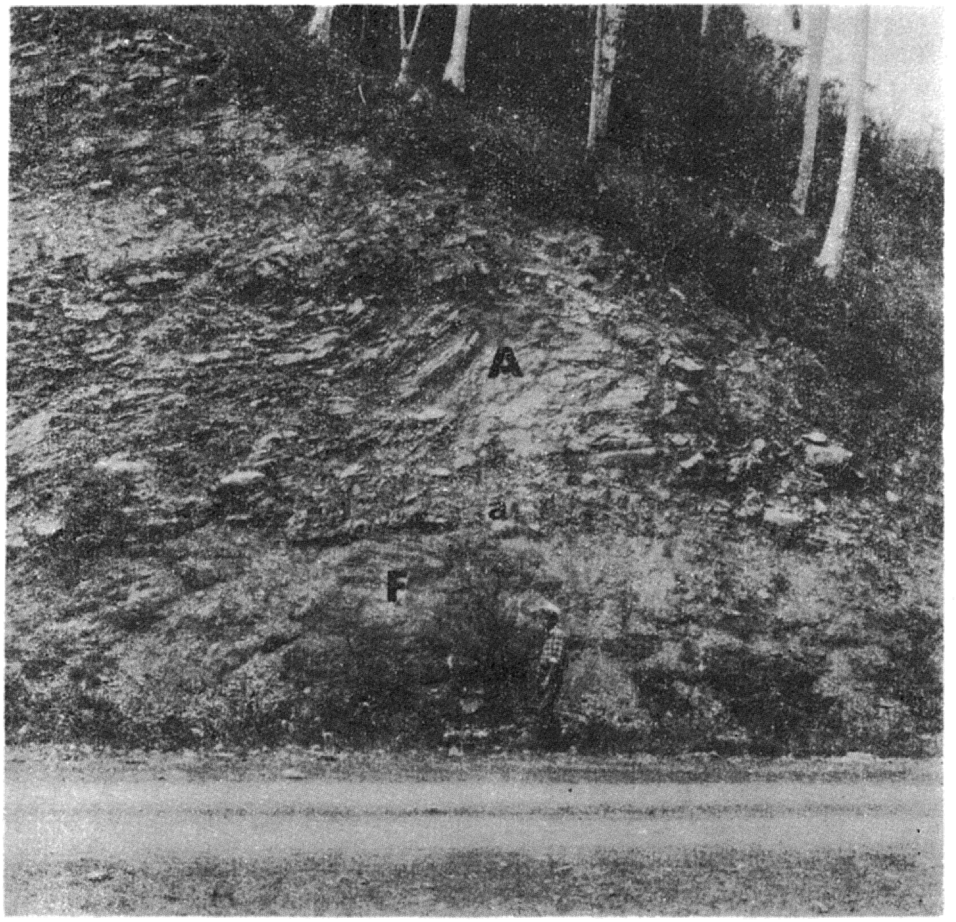

Fig. 4. Western part of locality No. *2* (cf. Text-fig. 2)
F Francisco Fm., *A* Artemisa Fm., *a* ammonite-bearing layers at the base of the Artemisa Fm.

The thickness of the sediments of the Francisco Formation cropping out in localities No. *1* and *2*, is estimated at 13 m. The contact between those sediments and the San Cayetano Formation is not visible here. Sandstones and shales of the San Cayetano Fm. are exposed in the southern escarpment of the road at a distance of about a dozen meters from exposure No. 2.

Upper part of the Francisco Formation is also well-displayed in the exposure near the main road from San Cristobal to Bahía Honda 1 km N of Cinco Pesos (locality No. *3;* Text-fig. 2; coordinates 282.100 and 328.800). The exposure is situated in the NE escarpment of the road, 500 m W of locality No. *2*. Here are exposed strata of the San Cayetano Fm., Francisco Fm. and Artemisa Fm. (Text-figs 5—6). In the lower part of the exposure there are visible thin-bedded fine-grained sandstones and shales of the San Cayetano Formation, overlied along a tectonic contact by a wedge of strata of the Francisco Fm. and the Artemisa Fm. The lowermost limestone layers of the Artemisa Formation yield ammonites. The set of limestones of the Artemisa Formation in turn, is overlain along a tectonic contact by sedi-

ments of the Francisco Formation. The latter are developed at the base as micritic laminated limestones, 5 m thick. The limestones are intercalated with a few thin layers of quartz and polymictic sandstones with clayey-siliceous cement; their composition is very close to that of sandstones occurring in the uppermost part of the San Cayetano Formation in the Cinco Pesos tectonic unit. The limestones yield occasional, badly preserved ammonites, as well as fish fragments and fine plant debris and sometimes small-sized calcareous concretions.

The limestones are overlain by shales with thin limestone intercalations, the same as those from locality No. *2*. The contact between the shales of the Francisco Formation and limestones of the Artemisa Formation is tectonically disturbed.

The contact between the Francisco Fm. and Artemisa Fm. is best displayed and least tectonically disturbed in locality No. *2*, which is, therefore, chosen as the type section of the upper boundary of the Francisco Formation (Text-fig. 4). The lower boundary of that formation is not visible in localities No. *1* and *2*, and is of tectonic nature in locality No. *3*; therefore it is not possible to choose a type section of the lower boundary at present. Observations made in other exposures and general knowledge of the lithology of the uppermost part of the San Cayetano Formation and lower part of the Francisco Formation make it possible to recognize that the sediments of the San Cayetano Fm. gradually pass into shales and limestones of the latter formation. This is the case *e.g.* in the Mogote Simón and La Baría sections. In sections characterized by a somewhat greater thickness of the transitional deposits of these two formations the boundary should be placed at the base of the first layer of limestone or shales with calcareous concretions.

The sediments of the Francisco Formation were laid down under conditions of quiet deposition, possibly below the transitional shelf zone (*sensu* Reineck & Singh 1973). This is indicated by the predominance of argillaceous and calcareous deposits often horizontally laminated, the occurrence of ammonites as well as the lack of sedimentary structures typical of very shallow zones of sedimentation with marked hydrodynamic activity. The occurrence of plant debris in some lithological horizons and intercalations of fine-grained sandstones suggest a sedimentary environment transitional to that of the San Cayetano Formation. In terms of lithology, the Francisco Formation comprises deposits transitional from the shales and sandstones of the upper part of the San Cayetano Formation to the limestones of the Artemisa Formation, the sedimentation of which ended in the Early Cretaceous. From the point of view of facies, the sediments of the Francisco Formation display some similarity to those of the Jagua Vieja Member of the Jagua Formation from the Sierra de los Organos (*cf.* Wierzbowski 1976). The occurrence of calcareous concretions in shales and limestones of the Francisco Formation is a result of early-diagenetic processes.

The deposits of the Francisco Formation are known from a few tectonic units cropping out between La Palma (= Consolación del Norte) and Soroa in south-western part of the Sierra del Rosario (Text-fig. 1). Presumably they also occur further westwards, north of the limestone belt of the Sierra de los Organos, but the lack of good exposures precludes the statement whether or not it is the case. The Francisco Formation ranges from a few to 25 m in thickness. There are some differences in lithology in the particular sections in the Sierra del Rosario. In the western part of that range the lower part of the formation bears numerous intercalations of marly limestones often brown-coloured in the weathering

zone. In some sections (*e.g.* the Brujíto section NW of Soroa) there are more numerous calcareous concretions, sometimes up to 0.5 m in diameter; they bear well-preserved ammonites of the genera *Vinalesphinctes, Perisphinctes, Mirosphinctes, Euaspidoceras, Cubaspidoceras, Glochiceras* and *Cubaochetoceras* (cf. Myczyński 1976, Wierzbowski 1976). Very thin, single intercalations of coquinas consisting of shell debris of pelecypods and ammonites of the genera *Euaspidoceras* and *Mirosphinctes* were found in some sections.

The Francisco Formation can be assigned to the late Middle Oxfordian (*cf.* discussion below).

It should be mentioned that some lithological features characteristic of the Francisco Formation are sometimes found in a few lithologic horizons in the upper part of the San Cayetano Formation in the Sierra del Rosario. This is chiefly the case of shales with calcareous concretions and limestone intercalations which were recognized in some sections of the upper part of the latter formation. However, the lithology of such horizons is not quite the same as that of the sediments of the Francisco Fm. Moreover, they are developed as intercalations within the typical sediments of the San Cayetano Fm., and thus clearly occur in a different lithostratigraphic setting.

AMMONITE FAUNA FROM THE BASE OF THE ARTEMISA FORMATION

LITHOLOGY OF THE AMMONITE-BEARING BEDS

The ammonite-bearing beds occur in the lowermost part of the Artemisa Formation at localites No. *2* and *3* (Text-figs 2—6). In locality No. *2* the ammonites were found in two limestone layers occurring directly above shales of the Francisco Formation (Text-figs 3—4). The Artemisa Formation is here represented by light-grey micritic limestones with thin shaly intercalations in the lower part of the sequence. The ammonite-bearing layers, each a few cm thick, are somewhat marly and nodular. Layers of the same type were found within the tectonic wedge which separates the sediments of the San Cayetano and Francisco formations at locality No. *3* (Text-figs 5—6). In the latter locality the ammonites occur also in two layers of somewhat marly limestones. Thin sections have shown that it is biomicritic and biomicrosparry sediment embracing micritic intraclasts (Pl. 2, Fig. 2). Fossils are represented by small ammonite shells (usually not more than the first whorl), prodissoconchs of pelecypods and small gastropods, often phosphatized. There are also fragments of structures close to that of the problematic algae of the genus *Cretacicrusta* Elliott, 1972, kindly determined by Dr. J. Kaźmierczak of the Institute of Paleozoology, Polish Academy of Sciences. Most of the ammonites are preserved as incomplete moulds and imprints, which suggest solution and possibly mechanical destruction of shells in deposit. Voids originating from solution of primary organic structures are sometimes filled with coarse, secondary calcite.

Fig. 5. Northern part of locality No. 3 (cf. Text-figs 2 and 6)
SC San Cayetano Fm., *F* Francisco Fm., *A* Artemisa Fm., *a* ammonite-bearing layers at the base of the Artemisa Fm.

At locality No. 3, the upper layer of the ammonite-bearing limestones is directly overlain by a dolomitic sediment yielding tubular phosphatic pellets a few mm in size, possibly of organic origin (? coprolites). Higher up there occurs a layer of a micritic limestone, 4 cm thick, with numerous fissures irregular in outline and infilled with sparry dolomite with numerous phosphatic structures (Pl. 2, Fig. 1). The top surface of that layer displays some small borings, possibly made by polychaetes. Such borings are also found within the layer, where they spread from the fissures penetrating the micritic rock. Some phosphatic structures also display borings.

The phenomena observed in the ammonite-bearing and overlying carbonate layers at the base of the Artemisa Formation evidence a decrease in rate of sedimentation. The occurrence of borings may even suggest some breaks in sedimentation. These phenomena may have resulted from action of currents disturbing the sedimentation, and from early diagenesis of the carbonate sediments of the basal part of the formation.

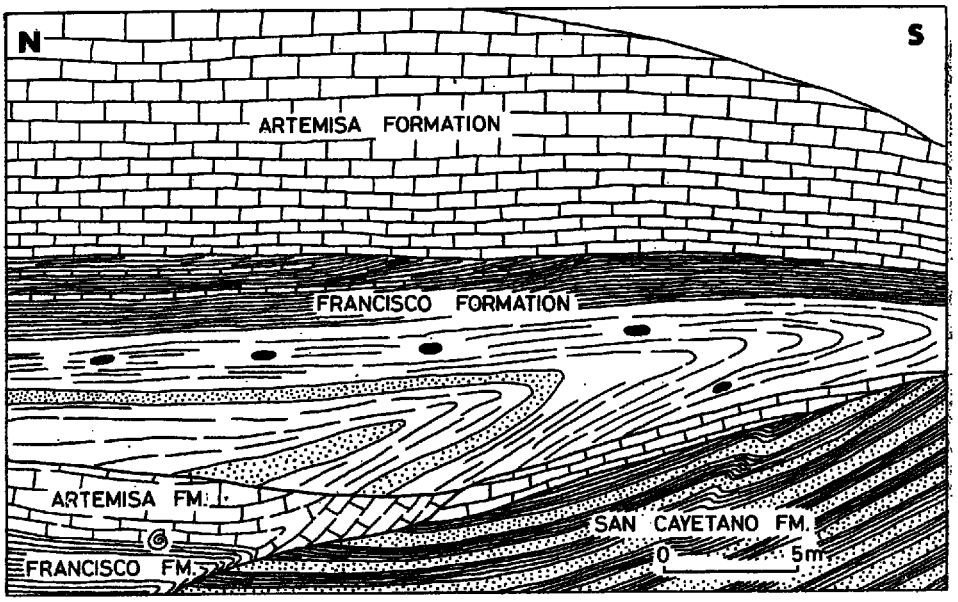

Fig. 6. Geological sketch at locality No. *3* (cf. Text-figs 2 and 5); occurrence site of the ammonites at the base of the Artemisa Fm. is indicated

THE AMMONITES

The occurrence of ammonites at the base of the Artemisa Formation was recognized in 1972 by A. Wierzbowski during an excursion with Miss M. L. de la Nuez and A. Pszczółkowski. Further fieldworks made it possible gathering a small collection of ammonites from localities No. *2* and *3*. It is housed in the Instituto de Geología, Academia de Ciencias de Cuba, La Habana. From that collection latex casts of two specimens (here referred as specimens "A" and "B") were available to the present authors. The second collection was gathered at the same localities at Cinco Pesos by J. Kutek, A. Pszczółkowski and A. Wierzbowski in 1973. That collection, housed in the same Institute, comprises the specimens numbered 2347—2352 and 2355—2370, covered by the present study.

The studied specimens are generally badly preserved. They represent calcareous moulds; some are partly dolomitized or phosphatized. Several specimens represent nuclei or fragments of whorls and none of them is complete. Moreover, some of them are deformed or heavily corroded. This results in the fact that none of them is sufficiently preserved for specific identification.

Nine of 26 specimens available undoubtedly represent the genus *Mirosphinctes*, and 8 — *Cubaspidoceras*. Two others presumably belong to *Mirosphinctes* and 4 — to *Cubaspidoceras*. Two heavily corroded may represent either *Mirosphinctes* or *Cubaspidoceras*. One specimen is an external imprint of a small, strongly involute ammonite without ornamentation, possibly belonging to the genus *Glochiceras*. The bulk of Cinco

Pesos fauna undoubtedly represents only two genera, *Mirosphinctes* and *Cubaspidoceras*.

The latter genera, *Mirosphinctes* and *Cubaspidoceras* were found in both localities No. *2* and *3*, where they are accompanied by *Liostrea mairei* (Loriol), kindly identified by Docent H. Pugaczewska of the Institute of Paleozoology, Polish Academy of Sciences.

Genus *MIROSPHINCTES* Schindewolf, 1926
(Text-fig. 7; Pl. 1, Figs 1—4)

Material. — Nine specimens (No. 2347, 2348, 2349, 2350, 2351, 2358, 2362, 2364 and 2365a) and two others poorly preserved (2361, 2363) presumably also belonging to that genus.

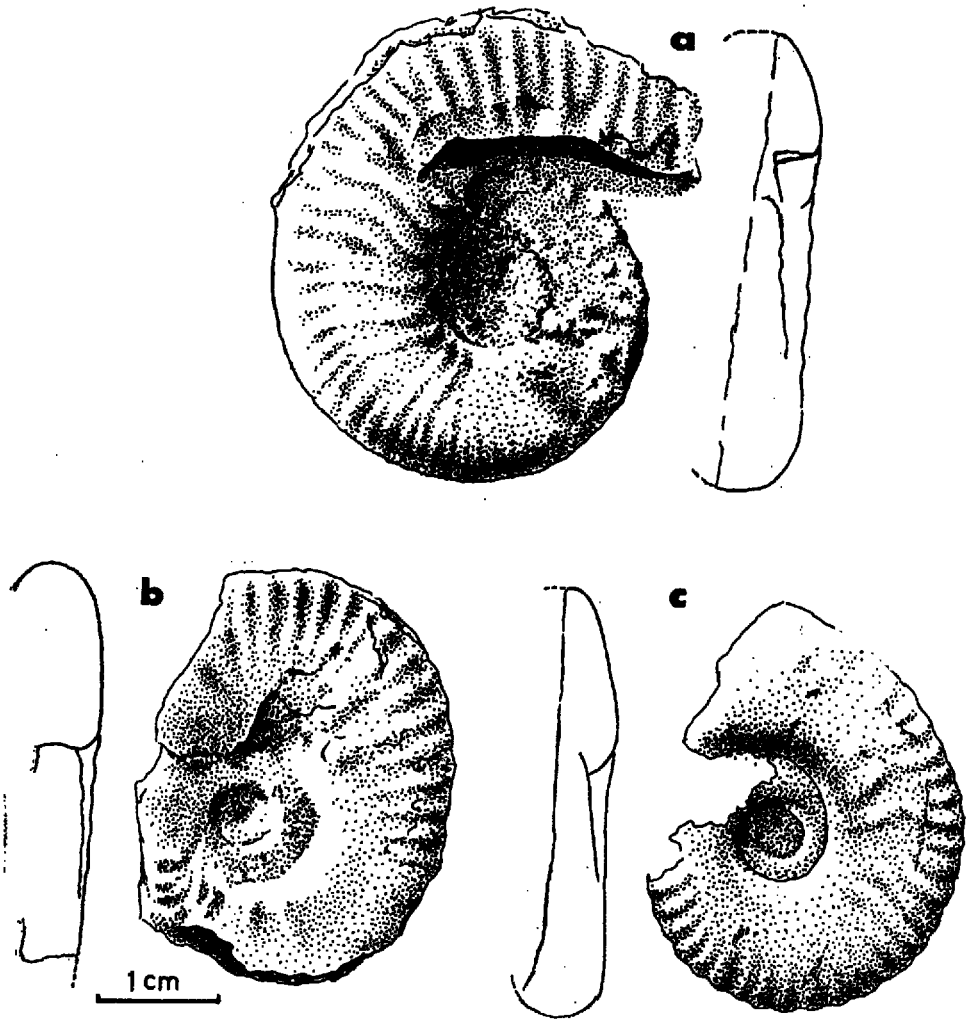

Fig. 7. *Mirosphinctes* spp.; **a** specimen No. 2351 (*cf.* Pl. 1, Fig 1), **b** No. 2362 (*cf.* Pl. 1, Fig. 2), **c** No. 2365a (*cf.* Pl. 1, Fig. 4)

There is no complete specimen with lappets preserved but weaking of ornamentation observable close to the end of spire in some specimens (*cf.* Text-fig. 7c; Pl. 1, Fig. 4; at 26–29 mm diameter of specimen No. 2365a), indicates proximity of the peristome. The specimens attain 20 to 36 mm in diameter (D); coiling moderately involute (in specimen No. 2365a — Ud = 33% D, and Wh = 37.5% D at D = 24 mm; in specimen No. 2351 — Ud = c. 31% and Wh = c. 39% at D = 32 mm; in specimen No. 2362 — Ud = 33% and Wh = 43% at D = 21 mm). Whorl section usually subrectangular with flattened whorl sides and fairly broad, weakly rounded ventral side; in a few specimens the whorl section is ovate (*cf.* Text-fig. 7a). Ornamentation of inner whorls usually more or less obliterated, consisting of loosely-spaced primary ribs; specimen No. 2364, with fairly densely spaced ribs is an exception here. The primary ribs are as a rule loosely spaced on outer whorl (13–15 in number per half-whorl), weakly prorsiradiate to almost rectiradiate, dividing usually into two commonly fairly rursiradiate ribs at or somewhat above the mid-height. The secondary ribs pass across the venter without any weakening. The primary and secondary ribs are strongly developed on the outermost whorl. Sutures more or less obliterated on all the specimens.

Despite of their poor preservation the specimens can safely be assigned to the genus *Mirosphinctes*. None of the specimens display parabolic nodes, probably because of insufficient preservation of the sculpture on inner whorls. The specimens differ from the majority of Cuban representatives of that genus, recently described by Myczyński (1976), in having more distant and stronger ribs on outer whorl; they seem to be rather closely comparable only with *M. minensis* Myczyński, 1976.

Genus *CUBASPIDOCERAS* Myczyński, 1976
(Text-figs 8–9; Pl. 1, Figs 5–8)

Material. — Seven specimens (No. 2352, 2357, 2365b, 2367, 2368 and 2370) and latex casts ("*A*", "*B*") of two others; moreover, 4 poorly preserved forms (No. 2356, 2360, 2366, 2369) presumably belonging to that genus.

The specimens represent various growth stages from about 20 mm to 110 mm in diameter (Text-figs 8–9; Pl. 1, Figs 5–8). Coiling moderately involute (approximate dimensions taken at latex casts *A* and *B* are as follows: B — Ud = 32%, Wh = 44% at D = 25 mm; A — Ud = 32%, Wh = 41% at D = 41 mm). Whorl section subrectangular to subtrapezoidal; whorl sides flattened; ventral side weakly rounded. Whorls about twice higher than thick. Umbilical wall steep; umbilical edge distinct.

The development of sculpture may be observed from about 20 mm diameter onwards (Text-fig. 8; Pl. 1, Figs 6–7). At that diameter of whorls there occur moderately strong, prorsiradiate, slightly concave ribs sometimes dividing irregularly into 2–3 secondary ribs. Fine tubercles, some of them parabolic in shape, are developed on the ribs at the umbilical edge and near the venter. There are more tubercles in the outer than in the inner row. The external tubercles are observable on the specimens up to a diameter of c. 40 mm (Text-fig. 8; Pl. 1, Figs 6–7); they disappear with increasing diameter, whereas the internal tubercles develop as spines directed inward over umbilicus (Text-fig. 9; Pl. 1, Fig. 8). This is accompanied by replacement of ribs by sets of striae spreading from the internal tubercles. Finally the internal tubercles also disappear, being replaced by poorly distinct swellings (Pl. 1, Fig. 5).

The specimens display all the features typical of the genus *Cubaspidoceras* Myczyński, 1976. They presumably fall within the limits of variability of the species

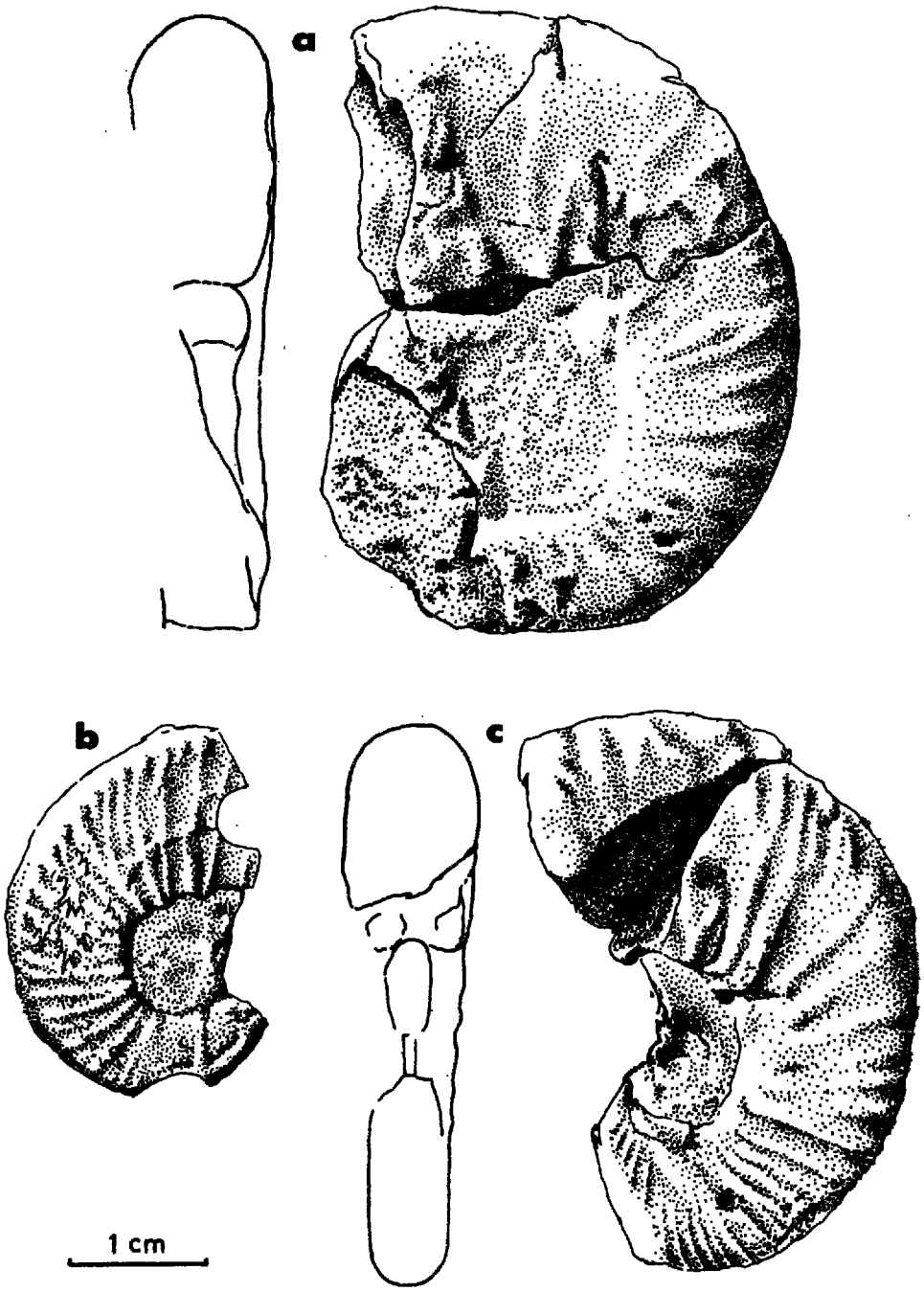

Fig. 8. *Cubaspidoceras* spp.; **a** specimen No. 2368 (*cf.* Pl. 1, Fig. 7), **b** specimen "B", **c** specimen No. 2367 (*cf.* Pl. 1, Fig. 6)

C. kuteki Myczyński, 1976, and *C. carribeanum* Myczyński, 1976, but their preservation is insufficient for any reliable specific identification.

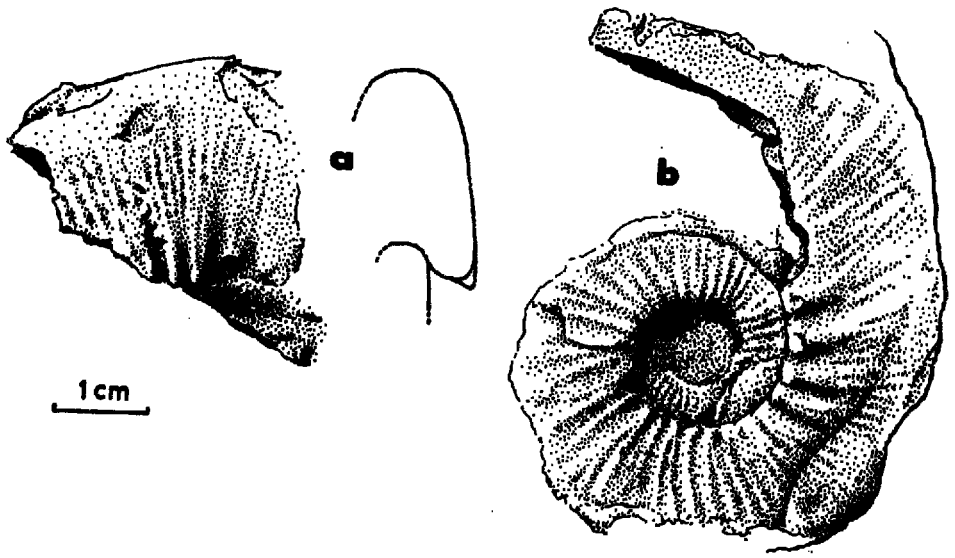

Fig. 9. *Cubaspidoceras* spp.; **a** specimen No. 2357 (*cf.* Pl. 1, Fig. 8), **b** specimen "A"

OXFORDIAN STRATIGRAPHY IN THE SIERRA DEL ROSARIO

The Jurassic sediments of the Sierra del Rosario were for a long time assigned to two formations: the San Cayetano Fm., comprising terrigenous rocks (mostly sandstones and shales), and the Artemisa Fm. developed as limestones. As Tithonian ammonites were known from the Artemisa Fm. (Imlay 1942, Judoley & Furrazola-Bermúdez 1968), it was regarded as Tithonian (or Portlandian-Tithonian). However, no ammonites were recorded from the lower part of the Artemisa Fm., so the possibility could not be ruled out that the formation also comprises some strata of pre-Tithonian age. No ammonites were also known from the San Cayetano Formation. Lower and Middle Jurassic age was generally assumed for the San Cayetano in the Sierra del Rosario and the Sierra de los Organos; and Upper Jurassic age was suggested for some upper part of the formation by some authors (*e.g.* Herrera 1961). There was a divergence of opinions as to the relationship between the Artemisa and San Cayetano formations. Some authors suggested an regional unconformity between these formations, related to the Nevadan orogeny (Furrazola-Bermúdez & al. 1964; Khudoley *in*: Khudoley & Meyerhoff 1971, Fig. 16), and the existence of a large stratigraphic gap between the Artemisa Fm. and the San Cayetano Fm. This gap was considered as roughly corresponding to the Oxfordian and Kimmeridgian (*cf.* Furrazola-Bermúdez 1965, Fig. 3). Other authors (*e.g.* Meyerhoff *in*: Khudoley & Meyerhoff 1971) assumed sedimentary continuity between the discussed formations. From this it would follow

that the whole Upper Jurassic is comprised in the sediments of the San Cayetano and Artemisa formations.

New data indicating sedimentary continuity between the Artemisa Fm. and underlying Jurassic strata were presented by Pszczółkowski (1971), who treated the latter as the uppermost part of the San Cayetano Fm. Subsequent field studies made it possible to distinguish the new Francisco Fm. for the strata separating the San Cayetano Fm. and the Artemisa Fm. In the light of the data available the sedimentary continuity between the Francisco Fm. and those under- and overlying seems to be beyond any doubt.

On the other hand, ammonites were recorded for the first time in the Sierra del Rosario from upper part of the San Cayetano Fm. (Myczyński & Pszczółkowski 1976), the Francisco Fm. (Wierzbowski 1976, Myczyński 1976), as well as the basal part of the Artemisa Fm.

The biostratigraphic interpretation of the ammonites will be made with reference to European Submediterranean subdivision of the Oxfordian stage (Table 1). The Middle-Upper Oxfordian boundary is placed at the base of the bimammatum Zone. This boundary corresponds to an abrupt change in the ammonite faunas in Europe (cf. Kutek & al. 1973).

Table 1

Correlation of lithostratigraphic units of the Sierra de los Organos and the Sierra del Rosario

Chronostratigraphic units		Sierra de los Organos		Sierra del Rosario
Tithonian		Guasasa Fm.	upper part of Guasasa Fm.	Artemisa Fm.
Kimmeridgian			San Vicente Member "Vinales Limestone"	
OXFORDIAN	UPPER: I. planula		breccias	
	UPPER: E. bimammatum	Jagua Fm.	Pimienta Member	Francisco Fm.
	MIDDLE: P. bifurcatus		Jagua Vieja Member	
	MIDDLE: G. transversarium		Azúcar-Pan Member/Zacarias Member	
	MIDDLE: P. plicatilis	San Cayetano Fm.		San Cayetano Fm.
	LOWER: C. cordatum			
	LOWER: Q. mariae			

In the upper part of the San Cayetano Fm. there were found a few ammonites of the genera *Perisphinctes* Waagen and *Discosphinctes* Dacqué. They may be compared with some forms known from the Middle Oxfordian of the Sierra de los Organos in Cuba and from Mexico; thus, they are indicative of Middle Oxfordian age of the strata bearing them (Myczyński & Pszczółkowski 1976).

In the bulk of the Francisco Fm., except for its uppermost part [1], there occurs an assemblage of ammonites comprising the following genera and subgenera: *Vinalesphinctes* Spath (with subgenera *Vinalesphinctes* and *Roigites* Wierzbowski), *Perisphinctes* Waagen (subgenus *Antilloceras* Wierzbowski), *Cubaochetoceras* Arkell and *Glochiceras* Hyatt. Such assemblage is of Middle Oxfordian age and it corresponds to the transversarium Zone and possibly lower part of the bifurcatus Zone (Wierzbowski 1976). Time equivalents of that assemblage are known from other parts of America (Wierzbowski 1976).

A different ammonite assemblage is characteristic of the uppermost part of the Francisco Fm. It comprises *Mirosphinctes* Schindewolf, *Euaspidoceras* Spath, *Cubaspidoceras* Myczyński, *Glochiceras* Hyatt and Ochetoceratinae (Myczyński, 1976). The still younger ammonite assemblage from the base of the Artemisa Fm., which comprises *Mirosphinctes, Cubaspidoceras* and *?Glochiceras,* is closely related to the former. The only significant difference between the two ammonite faunas seems to lay in the absence of *Euaspidoceras* in the younger strata.

The two assemblages just described seem to be incomparable with any assemblages recorded so far from America. They are younger than that present in the bulk of the Francisco Fm., so they are undoubtedly of bifurcatus or post-bifurcatus age. On the other hand, they appear to be markedly older than the Early Kimmeridgian ammonite assemblages known from several parts of America (*e.g.* the classical ammonite fauna of the Lower Kimmeridgian of Mexico — Burckhardt 1906, 1912; Imlay 1939). This suggests a pre-Kimmeridgian age of the Cuban assemblages.

More detailed stratigraphic conclusions may be drawn from the comparison of these Cuban assemblages with Oxfordian ammonite faunas of Europe. However, the comparisons may be made only at the generic level.

In the Oxfordian of Europe ammonites of the genus *Mirosphinctes* occur up to the top of the bifurcatus Zone where that genus is replaced

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[1] In the type sections of the Francisco Fm. (Cinco Pesos area) there were found only a few ammonites. The majority of ammonites recorded from that formation were found in calcareous concretions of the *"queso"* type in the Brujito area. In the latter area the ammonites mainly occur in the upper part of the formation. They represent two faunal assemblages derived from different concretions; however, it is not possible to establish the succession of these assemblages on the basis of field studies. One of the assemblages, described by Wierzbowski (1976), closely resembles the classical ammonite fauna from the Jagua Vieja Member of the Jagua Fm. from the Sierra de los Organos. Single representatives of that assemblage were also found in middle and lower parts of the Francisco Fm. in the Cinco Pesos area. Thus it may be stated that this is the older assemblage occurring in the bulk of Francisco Fm. Another assemblage closely resembles that known from the Pimienta Member of the Jagua Fm. from the Sierra de los Organos (Myczyński 1976). This assemblage comprises some elements known also from the ammonite assemblage of basal beds of the Artemisa Fm., described here. Thus, it may be assumed that this assemblage is limited to the uppermost part of the Francisco Fm. and that it is younger than the former.

by its evolutionary derivative, the genus *Epipeltoceras* (cf. Enay 1962, 1966; Enay & al. 1971; Mouterde & al. 1971). The genus *Mirosphinctes* was reported from the Montejunto Beds of Portugal together with ammonites known from the bimammatum Zone (*cf.* Ruget-Perrot 1961, França & al. 1964) but the analytic data available (Ruget-Perrot 1961) are insufficient for unequivocal statement whether, or not *Mirosphinctes* is actually present in beds of post-bifurcatus age. It may be added here that it is not represented in a rich ammonite assemblage of the hypselum Subzone of Poland, being studied by the present authors.

The genus *Euaspidoceras* present in the Lower and Middle Oxfordian in Europe is also common in the hypselum Subzone (the lower subzone of the bimammatum Zone), and it disappears in the upper part of the bimammatum Zone (*cf.* Dorn 1931, Enay & al. 1971).

The Cuban ammonites of the new genus *Cubaspidoceras* Myczyński, 1976, which undoubtedly belong to the subfamily Euaspidoceratinae Spath, seem to be most close to European ammonites allocated in the genus *Clambites*, especially to the species *C. aequicosta* (Qu.) and *C. schwabi* (Opp.) as well as to the species *?Neaspidoceras tietzei* (Neumayr) and its allies such as *?N. radisense* (d'Orb.). Both the Cuban and European forms display such features as moderately strong ornamentation, parabolic shape of tubercles and a trend to disappearance of sculpture towards the body chamber and to development of spines directed over the umbilicus. The latter feature is also displayed by the European *?N. tietzei* (Neum)[2]. The only important difference between *Cubaspidoceras* and these European forms seems to be related to more involute coiling and more compressed whorl section in the former. However, this difference is clear only in the case of the species *C. carribeanum* Myczyński, 1976.

The stratigraphic range of *Clambites* and *?N. tietzei* in Europe seems to be restricted to the bifurcatus and bimammatum zones (*cf.* Dorn 1931, Schuler 1965, Enay 1966, Behmel 1970, Sequeiros 1974). In sections where the bimammatum Zone may be divided into subzones, *Clambites* was reported from the hypselum and bimammatum Subzones, and *?N. tietzei* — from the hypselum Subzone. There are no data indicating that either *Clambites* or *?N. tietzei* extend higher in Upper Oxfordian sections in Europe than *Euaspidoceras*.

From the above it follows that the relations between the stratigraphic ranges of the discussed ammonites in Cuba are somewhat different from those established in Europe. In the former region *Mirosphinctes* and *Cubaspidoceras* range higher up than *Euaspidoceras*, whereas in the latter region *Euaspidoceras* and the ammonites comparable with *Cubaspidoceras* (*Clambites* and *?N. tietzei*) become extinct at about the same time but

[2] The synonymies of the species *Clambites aequicosta*, *C. schwabi* and *?Neaspidoceras tietzei* were given by Sequeiros (1974); *cf.* also Barbulescu (1974) for *?N. tietzei* (described as *Euaspidoceras tietzei*). It is debatable whether or not *?N. tietzei* can be assigned to the genus (or subgenus) *Neaspidoceras* Spath when there are taken into account the type species *N. wagurense* Spath and the original diagnosis of that genus (comprising "compressed flattened forms with the general aspect of *Euaspidoceras* but having the outer tubercle more prominent than the inner, in the adult stage as well as in the young", Spath 1931, p. 593). Possibly *?N. tietzei* (Neumayr) could be better accommodated in *Cubaspidoceras* than in *Neaspidoceras*.

later than *Mirosphinctes*. It remains an open question whether the differences are related to an earlier extinction of the genus *Euaspidoceras*, or a later extinction of *Mirosphinctes* in Cuba than in Europe.

The ammonite assemblage from the uppermost part of the Francisco Fm. is characterized by the occurrence of the genera *Mirosphinctes*, *Euaspidoceras* and *Cubaspidoceras*, and that from the basal part of the Artemisa Fm. by the occurrence of *Mirosphinctes* and *Cubaspidoceras*; *Euaspidoceras* being absent. The uppermost part of the Francisco Fm. is most probably of bifurcatus age. The older parts of that formation yield ammonites indicative of the transversarium Zone or, possibly, lower parts of the bifurcatus Zone (*cf.* Wierzbowski 1976). On the other hand, the occurrence of *Mirosphinctes* and *Euaspidoceras* is highly typical of the bifurcatus Zone of Europe, and ammonites comparable with *Cubaspidoceras* were recorded from that zone. Thus it can be suggested that the whole Francisco Formation is of Middle Oxfordian age.

The problem of the age of basal strata of the Artemisa Fm. is more troublesome. The occurrence of *Mirosphinctes* suggests bifurcatus age whereas the absence of *Euaspidoceras* favours younger but rather not post-bimammatum age of the strata. In any case, the Artemisa Fm. ranges down into the Oxfordian.

The Tithonian ammonites from the Artemisa Fm. of the Sierra del Rosario studied by Imlay (1942) and Judoley & Furrazola-Bermúdez (1968), are indicative of the Middle and Upper Tithonian (*cf.* Enay 1972). The field studies carried out by A. Pszczółkowski have shown that the Tithonian ammonites first appear about 50—70 m above the basal beds with *Mirosphinctes* and *Cubaspidoceras* in Cinco Pesos. The latter strata are of latest Middle Oxfordian or Late Oxfordian age and there is a sedimentary continuity within the Artemisa Fm.; from this it follows that the lower part of the formation, a few dozens meters thick, must correspond to the Upper Oxfordian, Kimmeridgian and Lower Tithonian. At present this formation is known to range up into the Lower Cretaceous (Pszczółkowski & al. 1975).

The stratigraphic correlation of Jurassic lithostratigraphic units of the Sierra del Rosario and the Sierra de los Organos accepted here (Table 1) does not differ from that presented by Wierzbowski (1976). It is worthy of mention that the ammonite assemblage comprising *Mirosphinctes*, *Cubaspidoceras* and *Euaspidoceras* occurs in the uppermost part of the Francisco Fm. in the Sierra del Rosario and in lower part of the Pimienta Member of the Jagua Fm. in the Sierra de los Organos, whereas the assemblage with *Mirosphinctes* and *Cubaspidoceras* but not *Euaspidoceras* — at the base of the Artemisa Fm. and in the upper part of the Pimienta Member. Therefore the basal strata of the Artemisa Fm. in the Sierra del Rosario may be considered a biostratigraphic equivalent of the upper part of the Pimienta Member (*cf.* Wierzbowski 1976, Myczyński 1976).

GENERAL CONCLUSIONS

The lithological data (*cf.* also Pszczółkowski 1971) evidence sedimentary continuity of the Francisco Formation with the underlying San Cayetano Fm. as well as with the overlying Artemisa Fm. The new biostratigraphic data point in the same direction. The ammonite fauna recently recorded from the upper part of the San Cayetano Fm. in the Sierra del Rosario (Myczyński & Pszczółkowski 1976) is close to the ammonite fauna from the bulk of the Francisco Fm. (which fauna, in turn, is closely comparable with the classical fauna of the Jagua Fm. from the Sierra de los Organos). The ammonite assemblage from the uppermost part of the Francisco Fm. is close to that from the basal strata of the Artemisa Fm.

Consequently, it appears that the area of the Sierra del Rosario was not affected by the Nevadan orogeny (*cf.* Furrazola-Bermúdez & al. 1964, Khudoley *in:* Khudoley & Meyerhoff 1971). The thin Francisco Fm. largely consists of incompetent rocks overlied by more competent carbonate rocks of the Artemisa Fm., and angular discrepancy is often observed at or close to the base of the latter formation (Text-fig. 6). However, this is not a primary unconformity resulting from Jurassic tectonic movements.

The correlation presented (Table 1) indicates that the gross lithologies of corresponding Jurassic strata from the Sierra del Rosario and the Sierra de los Organos do not much differ. The stratigraphic position of the top of the terrigenous San Cayetano Fm. is roughly the same in both areas. The Francisco Fm., comprising both terrigenous and carbonate deposits, appears similar to the Jagua Vieja Member of the Jagua Fm. from the Sierra de los Organos (the lithology of the Zacarías Member is transitional between those of the San Cayetano Fm. and the Jagua Vieja Member). The limestones of the Pimienta Member are comparable to some extent with the basal beds of the Artemisa Fm. The base of the latter formation is not strictly synchronous with the base of the Pimienta Member but the difference in stratigraphic position is not great. Massive limestones of the Guasasa Fm. (= Viñales Limestone *sensu* Hatten 1967, and Judoley & Furrazola-Bermúdez 1968) have their time equivalent in carbonates of the lower part of the Artemisa Fm. It follows that the general changes of facies from terrigenous through terrigenous--carbonate to carbonate took place at about the same time in the Sierra del Rosario and the Sierra de los Organos.

The presented stratigraphic data show that some Jurassic sediments of the Sierra de los Organos are thicker than their time equivalents in the Sierra del Rosario. The Jagua Vieja Member is 60 m thick, and the Pimienta Member 40—60 m thick. The Francisco Fm., roughly corresponding to the Jagua Vieja Member and some lower part of the Pimienta

Member (and possibly also to the Zacarías Member) is up to 25 m thick. The upper part of the Pimienta Member and the massive limestones of the Guasasa Fm. (up to 500 m thick) have their time equivalent in the lower part of the Artemisa Fm., the thickness of which ranges from a few dozens meters to 120 m in different sections up to the lowest strata with Tithonian ammonites.

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FORMACIÓN FRANCISCO Y UNA FAUNULA CON AMMONITES DEL OXFORDIANO EN LA FORMACIÓN ARTEMISA, SIERRA DEL ROSARIO, CUBA OCCIDENTAL

(Resumen)

Se establece la Formación Francisco del Oxfordiano en la Sierra del Rosario (Fig. 1—6) entre la Formación San Cayetano, subyacente, y la Formación Artemisa. Se describe también una faunula con los ammonites *Mirosphinctes* Schindewolf y *Cubaspidoceras* Myczyński (Fig. 7—9 y Lam. 1—2) de la edad oxfordiana, encontrada en la parte más baja de la Formación Artemisa (Fig. 3—6). Basandose en datos nuevos se discute la estratigrafía de los sedimentos jurásicos en la Sierra del Rosario. La sedimentación de la Formación San Cayetano del Jurásico Inferior (?) y Medio-Oxfordiano, de la Formación Francisco del Oxfordiano y de la Formación Artemisa del Oxfordiano-Cretacico Inferior fué continua, lo que indica que los movimientos nevádicos no afectarón la región estudiada.

De las nuevas correlaciones estratigraficas de las formaciones jurásicas de la Sierra del Rosario y de la Sierra de los Organos (Tab. 1) resulta que los fundamentales rasgos litologicos de los depósitos isocrónicos de ambas regiones se diferencian menos de lo que se suponía en algunos trabajos anteriores.

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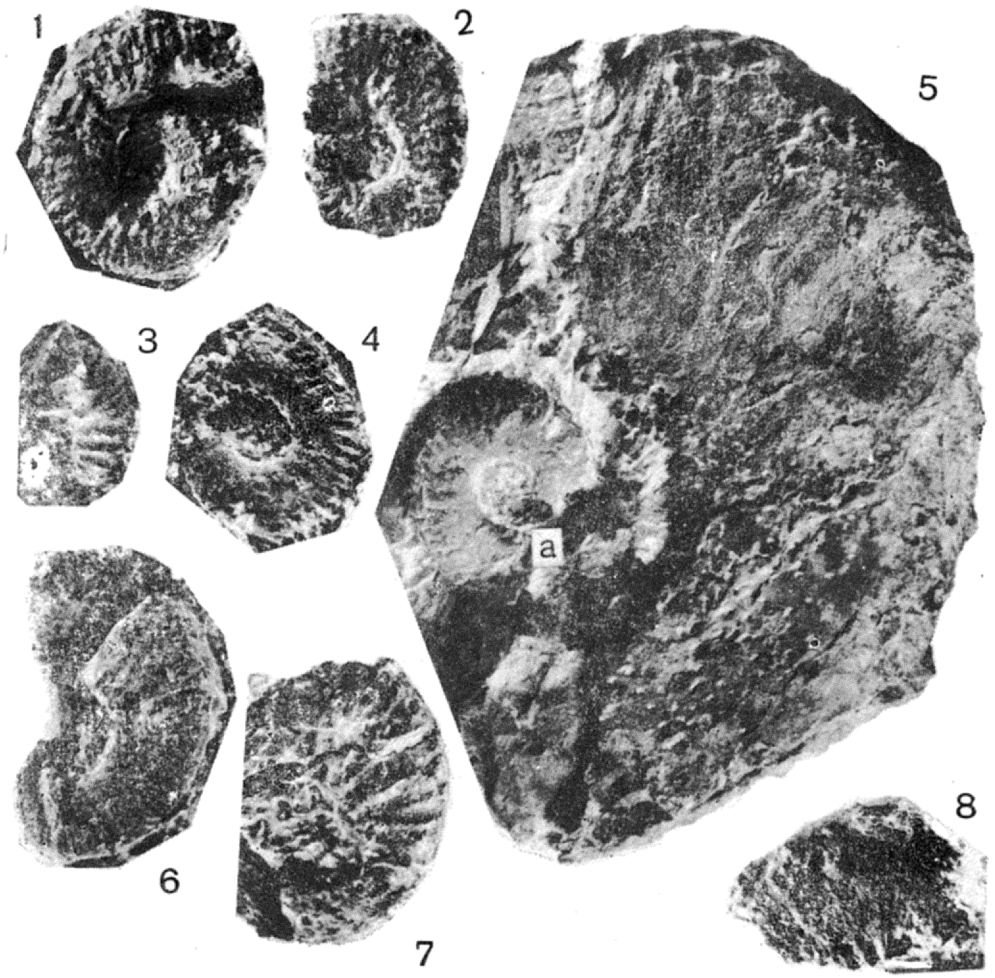
FORMACJA FRANCISCO I OKSFORDZKA FAUNA AMONITOWA Z FORMACJI ARTEMISA W SIERRA DEL ROSARIO, ZACHODNIA KUBA

(Streszczenie)

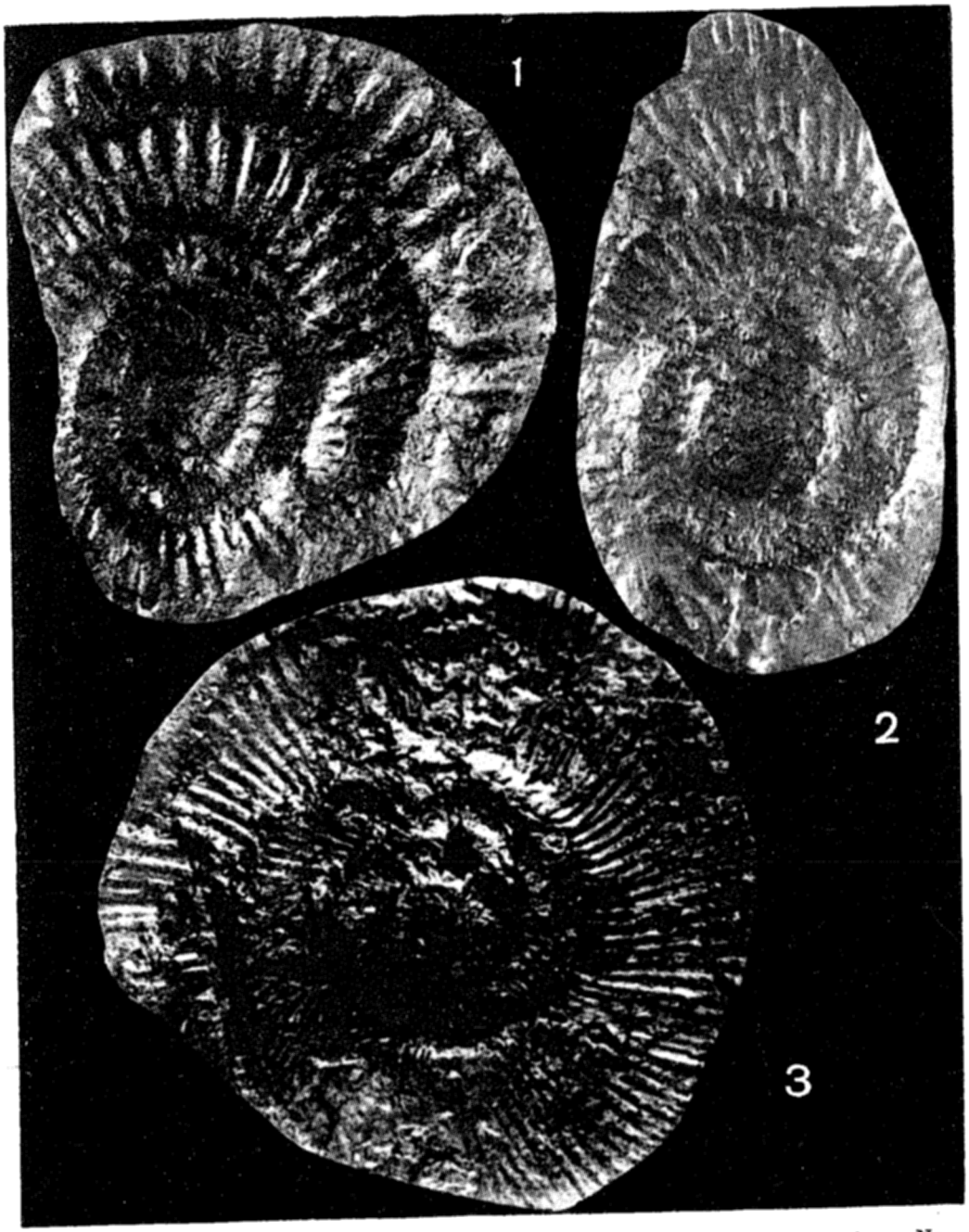
W obrębie osadów oksfordu w Sierra del Rosario w zachodniej Kubie ustanowiona została formacja Francisco (*por.* fig. 1—6). Opisano faunę amonitów należących do rodzajów *Mirosphinctes* Schindewolf i *Cubaspidoceras* Myczyński z najniższych warstw formacji Artemisa bezpośrednio nadścielających ustanowioną formację (*por.* fig. 7—9 oraz pl. 1—2). Warstwy zawierające wymienione amonity odpowiadają najwyższej części oksfordu środkowego albo niższej części oksfordu górnego (*por.* tab. 1).



1–4 *Mirosphinctes* spp.; specimens No. 2351 (Fig. 1), 2362 (Fig. 2), 2358 (Fig. 3) and 2365a (Fig. 4); the latter specimen (indicated as "*a*") is also shown lying inside the umbilicus of *Cubaspidoceras* in Fig. 5

5–8 *Cubaspidoceras* spp.; specimens No. 2365b, 2367, 2368 and 2357.

All photos of nat. size, taken by K. Zielińska



1 *Perisphinctes (?Dichotomosphinctes) cayetanensis* Myczyński, sp. n.; specimen No. 5060 (paratype), × 1.8

2 *Perisphinctes (?Dichotomosphinctes)* cf. *anconensis* Sánchez Roig; specimen No. 5063a, × 1.8

3 *Perisphinctes (Discosphinctes)* cf. *pichardoi* Chudoley & Furrazola-Bermúdez; specimen No. 5061, × 1.8