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Sedimentological reconnaissance of the San Cayetano Formation: an accumulative continental margin in the Jurassic of western Cuba

ABSTRACT: The lithology of the San Cayetano Formation is highly variable both laterally and vertically. The sediments exposed in the Sierra de los Organos were in most part deposited on a coastal alluvial plain by a river transporting the material a few hundred kilometers from the south. The sediments debouched to the sea formed an arcuate delta and some of it was redistributed by a longshore drift and turbidity currents. In the Sierra del Rosario a flysch is developed with localized occurrence of proximal turbidites. An accumulative continental margin developed due to the continuous subsidence. The complete ceasing of the clastic supply is reflected by a rapid transition from the San Cayetano Formation to the overlying carbonates.

INTRODUCTION

In the present paper, a general descriptive model of sedimentation of the Cayetano Formation is proposed. It is based mainly on the detailed observations carried out in the measured sections of this formation in various tectonic units of the Sierra de los Organos and the Sierra del Rosario in western Cuba (Fig. 1).

The term San Cayetano Formation is used here following the sense of Bermúdez & Hoffsteter (1959) and Bermúdez (1961). In this sense it is also commonly used by most geologists working at present in Cuba.

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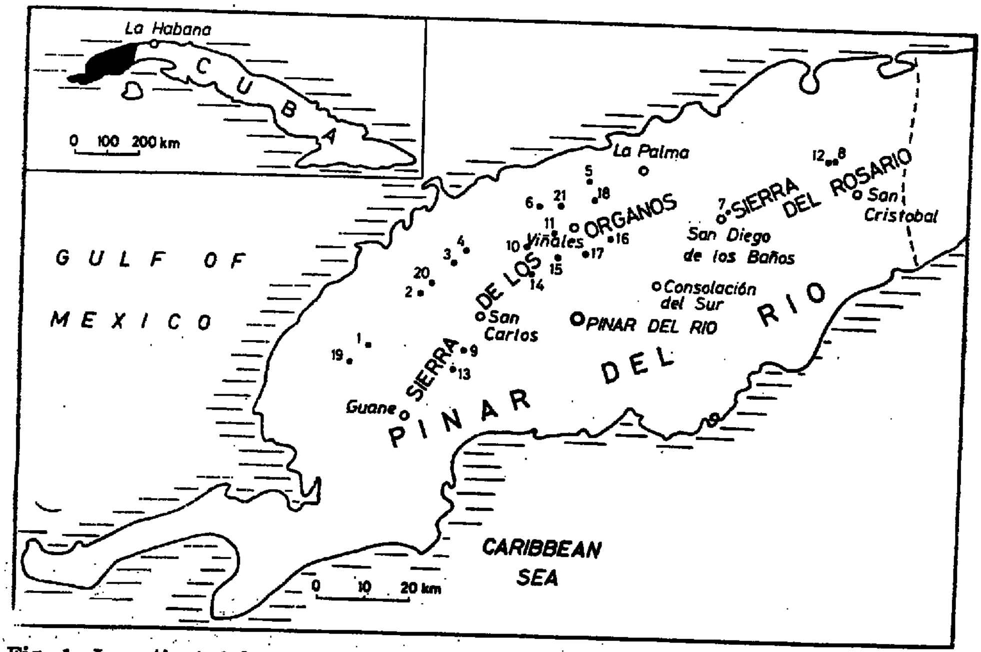


Fig. 1. Investigated localities (1—21) of the San Cayetano Formation in the Pinar del Rio province (inset shows its position in Cuba)

GEOLOGICAL SETTING

The San Cayetano Formation within the whole area of its occurrence is involved in extensive multiple thrust sheets of complicated internal structures. The formation is the oldest allochtonous unit and its base is unknown; its contact with younger deposits is in most places tectonic. However, the relation to the younger units is transitional (Hatten 1957, 1967; Pszczółkowski 1971; Meyerhoff & Hatten 1974; Wierzbowski 1976; Kutek & al. 1976). The thickness of the formation cannot be reliably determined, but it probably ranges from a few hundred meters to a maximum of about 1500 m in the nothern part of the Sierra de los Organos.

The age of the uppermost part of the San Cayetano Formation in the Sierra del Rosario has been recently determined as Middle Oxfordian (Myczyński & Pszczółkowski 1976). The transition to the younger formations seems to have taken place at roughly the same time within the whole area of occurrence (Wierzbowski 1976). The fossils known from the lower parts of the formation, such as *Trigonia*

(Vaugonia) krommelbeini A. Torre (*cf.* Krömmelbein 1956, de la Torre 1960), *Cuspidaria* sp., *Modiolus* sp., *Quenstedtia* sp. (*cf.* Hatten 1957, de la Torre 1960), *Phlaebopteris cubensis* Vakhr. (*cf.* Vakhrameev 1965, 1966), poorly preserved pollen and spores (*cf.* Hoffmeister & al. 1954), and fossil wood of *Araucarioxylon* sp. (Reymanówna & Haczewski, *in prep.*) do not permit conclusive age determinations. The problem of the downward age extent of the San Cayetano Fm. seems to remain open.

The results of the petrographical analysis (Dr. B. Łącka, *written comm.*) indicate the source area built mainly of terrigenous sedimentary and low grade metasedimentary rocks. In the deposits of the facies *D* defined below, and in the flysch sequences small amount of volcanic material and of glauconite was detected.

The formation is deeply weathered so that the exposures favourable for sedimentological study are found mainly in some deeply incised streams and rivers (Pl. 1).

The facies changes within the formation take place within short distances vertically as well as laterally which is evidenced by the data from the Matahambre coper mine (Poplavski 1966). During the tectonic movements the rock bodies of different competence were commonly detached, and the resulting decollements are a conspicous feature of the tectonic style of the investigated sequence.

PREVIOUS OPINIONS ON THE SEDIMENTARY ENVIRONMENT

The depositional environment of the San Cayetano Formation was variously interpreted, as being continental (Krömmelbein 1962; Korin & al. 1973), lacustrine (Bermúdez 1961), parallic-lagoonal (Rigassi-Studer 1963, Meyerhoff 1967, Khudoley & Meyerhoff 1970, Judoley & Furrazola--Bermúdez 1971, Somin & Millan 1972), deltaic (Pszczółkowski 1971), delta and flood plain to prodelta slope and deep water (Meyerhoff & Hatten 1974), shallow marine (Imlay 1942, Hatten 1957), or deep-sea environment of flysch deposition (Pokrishkin & Shirokov 1966, Jäger 1968, Santrucek 1972). It is to be noted that only very few of the authors referred to observations of the assemblage of sedimentary features. Jäger (1968) mentioned even the detailed graphic log of sedimentary structures measured in a gallery of the Matahambre mine, but the log was not illustrated. The sequence of sedimentary structures typical for turbidites, discerned in this section prompted that author to suggest a flysch character for the formation as a whole disregarding its lithologic variability evidenced in the same paper (Jäger 1968, p. 351—352).

Meyerhoff & Hatten (1974, p. 1210) were the only who noticed the variability of sedimentary features in different thrust sheets and indicated the necessity of the detailed field mapping of sedimentary features in San Cayetano.

METHODS OF STUDY

The study was based on detailed analysis of the selected sections rather than on the interpretation of the whole succesion and on the lateral relations of various facies. Such a way was chosen because the original spatial relations of various thrust sheets and of detached fragments could not be reliably determined.

The outcrops of the San Cayetano Formation were investigated in all major tectonic units (Fig. 1). The localities of important faunal and floral findings were also studied. The locations were selected taking into account the information from other geologists cooperating in elaboration of the geologic map of the Pinar del Rio province, and the study of aerophotos and maps. The intention was to demonstrate all major facies in favourable exposures.

The discussion regards mainly the physical aspect of sedimentation. Paleontological analysis are still in progress, and chemical features of sediments are strongly obliterated by processes both of metamorphism, and of tropical weathering.

The grain-size estimates were made using the transparent grain-size comparator similar to that described by Lewis & al. (1970).

FACIES DESCRIPTION AND INTERPRETATION

Within the observed sections nine facies were distinguished. The term facies is used here to refer to parts of the formation, distinguished by their megascopic lithologic features. Combining of different sections within the same facies does not implay necessarily the uniform environment of deposition. The recognized facies are described below, and for easier reference every facies is designated by a capital letter (*A-I*). A type section illustrates each of the facies. The description is followed by an interpretation of the conditions of sedimentation and by indications of possible environments where these conditions may have occurred.

FACIES A: LARGE-SCALE CROSS-BEDDED SANDSTONES

The type section (Fig. 2a) was measured in a ravine of a stream cutting the sharp rocky-hill ridge called Borraga (long. 84°11′33″ W, lat. 22°20′37″ N; locality *1* in Fig. 1).

Description. The facies typically consists of sandstones of various grain-size with some subordinate pebbly sandstones or pebbly conglomerates with pebbles ranging up to 45 mm. Pelitic rocks are rare. Most beds are cross-laminated. In fine- or very fine-grained sandstones the tabular to wedge-shaped sets (30—80 cm thick) of low-angle cross-laminations (Pl. 2, Fig. 1) are the most common. The coarser grained beds are frequently horizontally laminated with regular, parallel laminae, 1—4 cm in thickness. Such laminated sandstones sometimes contain dispersed flat pebbles, up to 15 mm in diameter.

The erosional structures are common within the facies, ranging from planar or uneven extensive surfaces truncating the lower bed, through cut-and-fill struc-

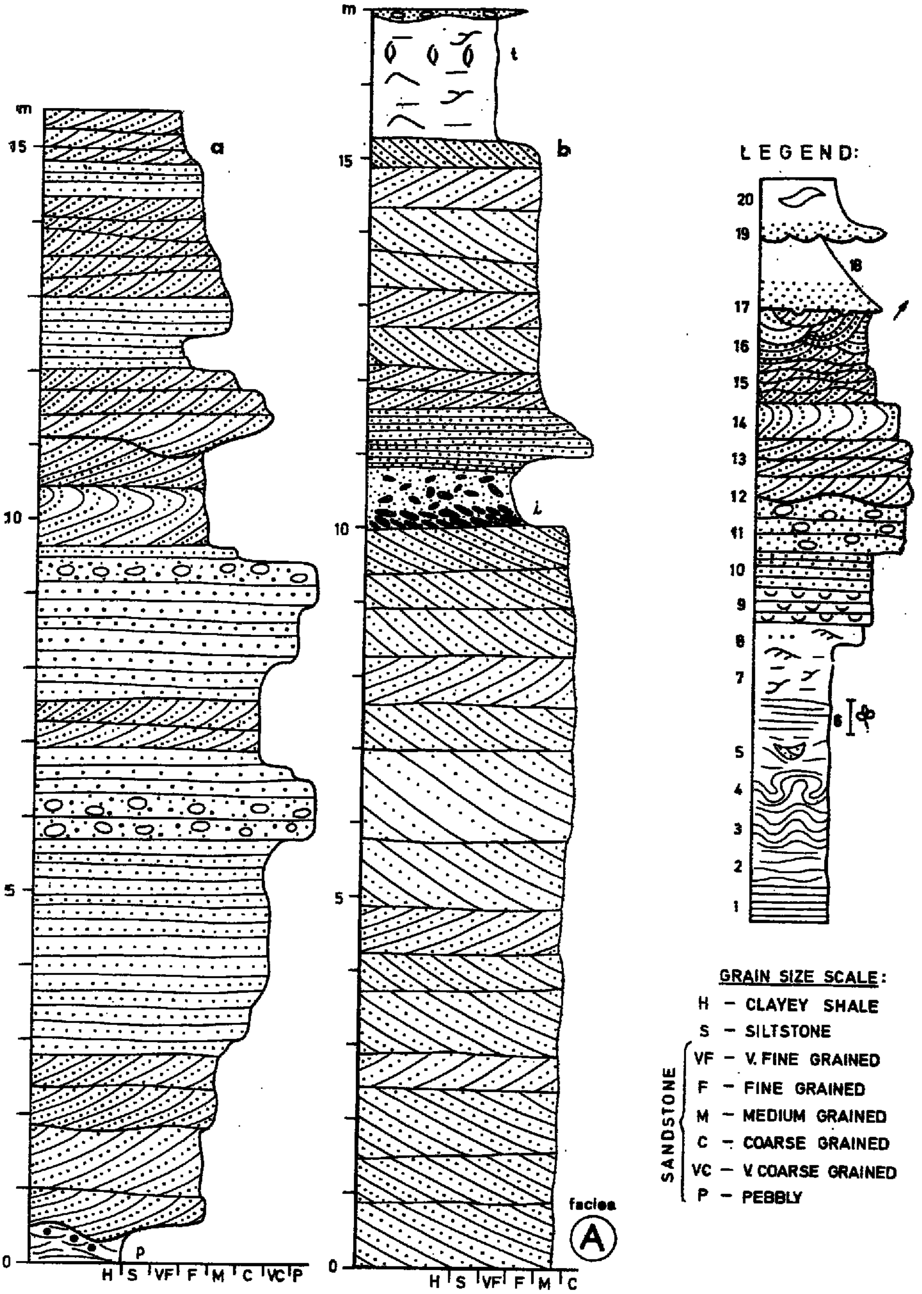


Fig. 2. Facies A: large-scale cross-bedded sandstones

a — alluvial deposits (section at locality *1*, cf. Text-fig. 1); b — tidal channel or inlet deposits (section at locality *3*, cf. Text-fig. 1)

Legend (also for Text-figs 6—13):

1 horizontally laminated shales, *2* indistinct, uneven lamination in shales, *3* shales with wavy lamination, *4* convolute lamination, *5* sunken ripples, *6* abundant plant detritus, *7* flaser bedding, *8* ripple bedding, *9* lumachelle, *10* horizontally laminated sandstones, *11* pebbles dispersed in sandstones, *12* sharp uneven erosional contact, *13* large-scale cross bedding, *14* deformed cross-bedding, *15* trough cross-bedding of low and medium scale, *16* trough cross-bedding of large scale, *17* hieroglyphs on soles, and azimuth of current direction, *18* graded bedding, *19* load-casted sole of sandstone bed, *20* rip-up clasts

p pyrite spheres, *t* moulds of *Trigonia* shells, *w* wrinkle marks, *b* ball-and-pillow structures, *c* septarian nodules, *d* mud diapirs, *m* armoured mud clasts, *i* intraformational conglomerates tures to greater channels (Pl. 2, Fig. 2) with denivelations exceeding one meter visible within the limits of a single outcrop. The channels are filled with quartz-pebble conglomerate, structurless sandstone with dispersed intraformational pebbles up to 2 cm, and horizontally or cross- laminated sandstones. Some coarse grained, thick sandstone beds display ellipsoidal parting giving rise to sandstone balls up to 80 cm in diameter.

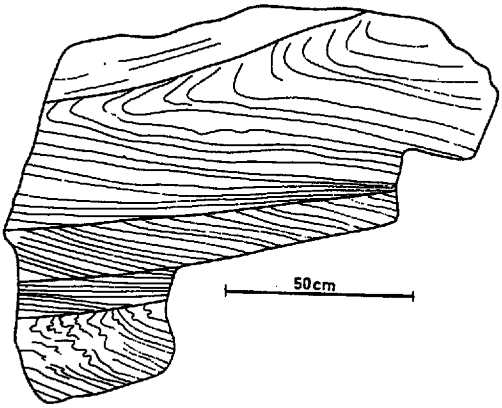


Fig. 3. Recumbent-fold deformed cross--bedding; locality *15* (cf. Text-fig. 1)

Many large sets of cross-laminae display conspicous deformation structures ranging from simple, fairly regular overturned folds in the upper part of the sets (Fig. 3), through regularly spaced diapir-like upwellings of laminae growing from some height above the lower boundary of the set with the degree of deformation increasing upward (Fig. 4), to chaotic disturbance. In the upper part of deformed beds, lamination is often blurred (Fig. 5; Pl. 2, Fig. 3). The three types of deformation are closely related and seem to have developed simultaneously in many cases. These deformations are probably the structures referred to by Hatten (1957) and Meyerhoff & Hatten (1974) as the submarine slumpings. True slumpings with detachment and subsequent gravitational transportation of some part of nonliquefied sediment were not observed by the author.

In the section exposed at long. 84°02′13″ W, lat. 22°31′23″ N (locality *3* in Fig. 1), a bed of intraformational conglomerate 80 cm thick was encoutered (Fig. 2b). In the basal part it displayed imbrication of clasts ranging up to about 3 cm. In the uppermost part of the bed the conglomerate is horizontally laminated.

Conditions of deposition. The original bedforms that gave rise to the large--scale sets must have been the megaripples moved over the bottom by a current in conditions of the upper part of the lower flow regime (*cf.* Simons & al. 1965). The

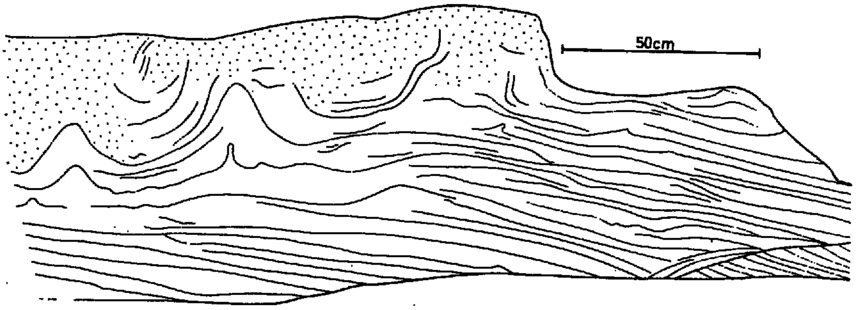


Fig. 4. Deformed cross-bedding with diapir-like upwellings of laminae; dotted areas mark structureless sandstone; locality *15* (cf. Text-fig. 1)

tabular sets owe their origin to straight-crested megaripples while trough-shaped sets were deposited by migration of less regular forms. In the tabular sets the major part of original ripple height may be preserved, while in the trough-shaped ones usually only the basal part of the sets escapes a subsequent erosion (*cf.* Harms & Fahnestock 1965).

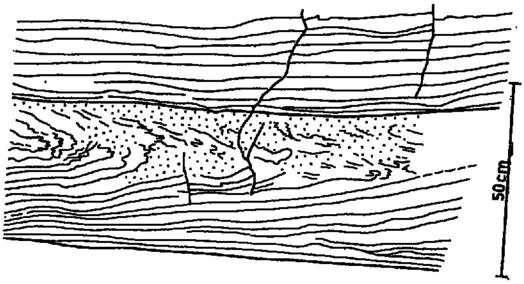


Fig. 5
Recumbent-fold deformed cross-bedding with obliterated lamination; dotted areas mark structureless sandstone; locality *17* (cf. Text-fig. 1)

The thick horizontal lamination is ascribed to the deposition of sand and pebbles transported in conditions of the plane bed phase of the upper flow regime (Simons & al. 1965).

The erosional upper boundaries of the cross-laminated sets are due to erosion in front of the migrating bedforms. The erosional channels and some cut-and-fill structures and intraformational conglomerates reflect the periods of increased flow energy.

The deformational structures of the described types are known from various cross-bedded deposits, and their occurrence was recently reviewed by Allen & Banks (1972). The recorded deformations correspond with the first two types distinguished by Allen & Banks (1972). These authors explain the regular recumbent folding of the foreset laminae by the action of a current drug on the surface of liquefied cross-laminated deposit. The regularly spaced diapir-like upwellings of the sandy laminae suggest that vertically oriented forces took part in the deformation process.

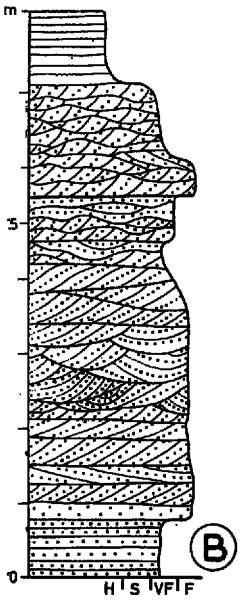
Depositional environment. The conditions required for deposition of this facies are most likely to be encountered in fluvial environment. The postulated migration of great bedforms with straight crests should have taken place in sufficiently wide channel and could occur during high water stage. It is noteworthy that such a type of bedding is only rarely reported from ancient alluvial deposits. Migrating sand waves of that type were reported from rivers of large discharge as the Brahmaputra (*cf.* Coleman 1969) and other rivers (*cf.* Allen 1976). According to the former author a better continuity of the crests is assumed at a grater depth of water. When foreset slopes are less inclined than an angle of repose, the erosional scours downstream of the crest are absent. This could explain the common preservation of these forms in the San Cayetano Formation as compared with the sand waves depositing in the form of trough cross-bedded units, which have much less preservation potential.

The point-bar sequences were not encountered, this suggesting a low-sinusoity geometry of the alluvial channels. The rapid lateral shifting of the channels would account for a dominance of the channel deposits within the alluvial plain.

Another environment probable for at least a part of the facies *A* is that of tidal channels or tidal inlets, where migrating sand waves are commonly encountered giving rise to large sets of cross-laminae (*cf.* Reineck & Singh 1973, Allen 1976). The similarity of some sequences deposited in tidal environment to alluvial sequences was stressed *e.g.* by Klein (1972). One of the presented sections (Fig. 2b) is interpreted to be deposited in a tidal inlet or channel, as evidenced by a herringbone cross-stratification (*cf.* also diagram *3* in Fig. 15). The lag concentrate of mud pebbles in this section is not indicative of the environment as it may occur in both regarded here. The well preserved moulds of the pelecypods *Trigonia* found in calcareous mudstones immediately above the sandstones are another indication of marine environment. The deposits of migrating tidal inlets have a high preservation potential and may form a significant part of fossil transgressive sequences, as was pointed out by Kumar & Sanders (1974).

FACIES B: MEDIUM AND SMALL-SCALE TROUGH CROSS-BEDDED SANDSTONES

The type section (Fig. 6) was measured in the same outcrop as the section presented in Fig. 2a, but 40 m below.



Description. The facies consists mainly of fine grained sandstones with trough cross-lamination in sets 15—50 cm thick. In very fine- or fine grained sandstones, cross-lamination in sets 6—15 cm thick is frequent. In cuts perpendicular to the axis of the troughs assymetrical infillings are commonly discernible. The laminae show sometimes wavy irregularities, but deformations similar to those in the facies *A* are absent. The boundaries of the sets are commonly uneven and wavy.

Conditions of deposition. The beddings observed are due to migration of megaripples and ripples with irregular crests in the conditions of the lower flow regime. The assymetrical infillings of the troughs are due to the sediment input from the side rather than by advancing fronts of the migrating bedforms.

Fig. 6

Facies B: medium- and small-scale trough cross-bedded sandstones, locality *1* (cf. Text-fig. 1); legend as for Text-fig 2

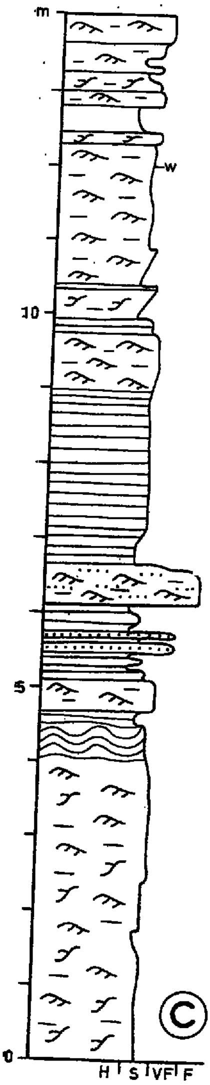
Depositional environment. This facies is always related to the facies *A* and is interpreted to represent mainly alluvial deposits.

FACIES C: SILTSTONES AND SHALES WITH RIPPLES AND FLASER BEDDING

The type section (Fig. 7) was measured at the left bank of the Macurije river, some 150 m upstream of the bridge on the Mantua — Matahambre road (long. 84°03′54″ W, lat. 22°29′20″ N; locality *20* in Fig. 1).

Description. The facies consists mainly of bedded siltstones, shales, and rarely very fine grained sandstones with indistinct layer boundaries. Within the siltstones and sandstones ripple bedding and flaser structures dominate. The ripples are low and flat, sometimes having the form of ill-developed ripple-drift cross-lamination. The lamination is hardly visible due to little differentiation of the material. In some layers the laminae display wavy deformations. On the parting surface (marked *w* in Fig. 7) of a thick silty-sandy layer with wavy lamination, a network of microripples with wavy crests 1 mm high, 3 mm wide, roughly parallel one to another and repeatedly interconnected, was found. The upper part of the section begins with an intraformational conglomerate composed of thin, flat mud-clasts. Above the conglomerate rhythmic deposits predominate. The lower boundaries of the cycles are sharp. Horizontally or wavy laminated siltstones or very fine grained sandstones lie immediately above, and they grade upwards to shales with lenses of siltstones and flaser structures or ripple bedding. Some cycles terminate with structureless shale.

Conditions of deposition. The discussed deposits were laid down by low-energy currents capable of transporting of silt and fine sand only. The ripple-drift cross-lamination occurring in incipient form within the normal ripples is related to an addition of some sediment from suspension (*cf.* Jopling & Walker 1968). The flaser structures are another indication of suspended sediment being added to the developing ripple lamination. The microripple structure resembles the wrinkle marks described by Häntzschel & Reineck (1968, p. 17, Pl. 6); their origin was explained experimentally by Reineck (*cf.* Reineck & Singh 1973, p. 56) as resulting from action of the wind blowing over a partly cohesive sediment surface covered with a thin film of water. The flat mud pebbles probably originated from redeposition of desiccated and cracked mud. The cyclic deposits reflect repetitive influxes of sediment-laden waters at the flow regime gradually decreasing from the plane bed phase to the rippled bed phase. Some shales could have settled from suspension. The wavy deformations in finer-grained beds have supposedly resulted from inversed density gradient (*cf.* Anketell & al. 1970).



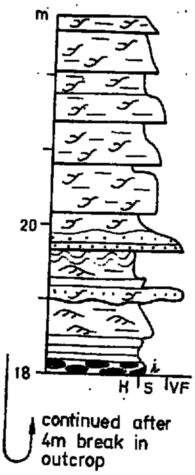


Fig. 7. Facies C: siltstones and shales with ripples and flaser bedding, locality *2a* (cf. Text-fig. 1); legend as for Text-fig. 2

Depositional environment. The two environments possible are those of alluvial flood plain (*cf.* McKee & al. 1967) and of tidal flats. The features observed in the investigated section are not conclusive in that respect. The well known exposure yielding fern fronds in the road cut between Matahambre and La Esperanza represents probably the deposits of alluvial plain origin.

FACIES D: MUDSTONE AND SANDSTONE WITH WAVE RIPPLES AND LUMACHELLES

The type section (Fig. 8) was measured along a roadcut forming cliffs at both sides of the road south of La Mina mogote (long. 83°39′38″ W, lat. 22°41′31″ N; locality *18* in Fig. 1. This section is presented here in spite of its high degree of weathering, because it represents an undisturbed sequence of the uppermost part of the San Cayetano Formation with the transition to the Jagua Formation (*cf.* Wierzbowski 1976). The unweathered rocks of this facies are exposed in the bed of the San Vicente river, 2.5 km WSW from the measured section. In the illustration (Fig. 8) the sandstones are not subdivided into grain-size classes because weathering processes made impossible the correct estimations.

Description. The sequence consists mainly of siltstones, finegrained sandstones and thin-bedded shales. Ripple and flaser bedding dominates. The ripple bedding consists of symmetrical ripples which are well visible at the road San Vicente — Ancon at long. 83°43′52″ W, lat. 22°40′21″ N (locality *1* in Fig. 1; *cf.* Pl. 3, Figs 1—2). In the type section, thin lumachelle beds consisting of small silicified oyster shells (*cf.* Pugaczewska 1976) repeatedly occur. Two sandstone beds without any visible internal structures are present in the middle part of the section. Below the lower one, a horizon of well developed ball-and-pillow structures appears. The bolsters are up to 70 cm in size, and are emplaced in a slightly finer-grained sand; and these structures do not show any indications of lateral displacement. In the uppermost part of the section the grain-size of deposits diminishes while the number of lumachelle beds increases marking the transition to thin bedded lumachelle deposits of the lowermost part of the Jagua Formation.

Conditions of deposition. The oscillation ripples and flaser bedding suggest sedimentation in an environment of agitated

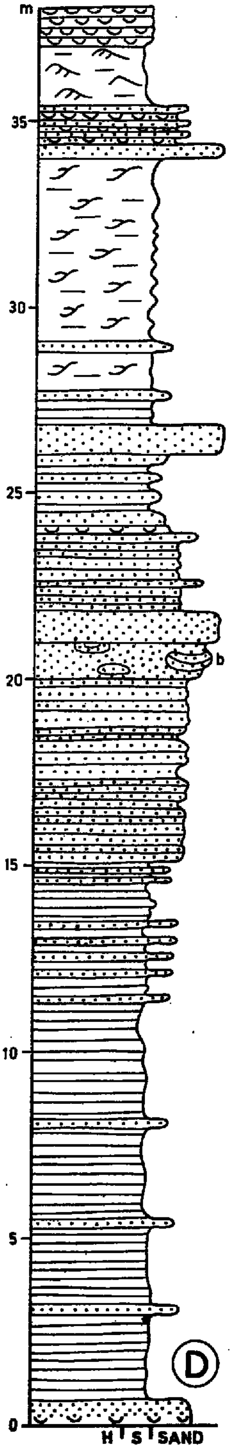


Fig. 8. Facies D: mudstones and sandstones with wave ripples and lumachelles locality *18* (cf. Text-fig. 1); legend as for Text-fig. 2

water with only little sand available. The lumachelle beds suggest shallow marine, near-shore conditions. The ball and pillow structures are due to sinking of sand into the underlying layer in response to the reversed density gradient (*cf.* Anketell & al. 1970).

Depositional environment. The fossil content indicates marine environment. Non-graded sand bodies of good lateral continuity may be of littoral, shallow marine or beach origin. Of beach character seem to be the laminations reported by Dr. A. Pszczółkowski (*personal comm.*) from the vicinity of El Abra (long. 83°46′05″ W, lat. 22°40′02″ N; locality *6* in Fig. 1).

FACIES E: BLACK SHALES WITH SPHERES

The type section (Fig. 9) was measured in the Mantua River (long. 84°13′10″ W, lat. 22°19′32″ N; locality *19* in Fig. 1).

Description. The facies consists of black shales lacking any lamination, but displaying well developed fissility. In the lower part of the section ellipsoidal septarian nodules up to 30 cm in diameter occur. Their contact with the embedding shales is gradual but rapid. The fissility planes of the shales strictly adjust to the shape of the septaria. Small pyrite spheres (up to 20 mm in diameter) occur commonly throughout the shales.

Within the shales isolated sheets of sandstone beds appear, as the one visible at the upper part of the type section. This consists of fine- to medium grained, horizontally bedded sandstone. Inclined bedding of an angle of less than 5° can be discerned too. A bed of mudstone lying between the sandstones contains scattered, flattened and sunk ripples. In one place a diapir-like intrusion of the mudstone pierces throughout the overlying sandstone beds. Beyond the diapir the upper contact of the deformed mudstone is smooth and undisturbed. The diapir is truncated by a horizontal sandstone bed 60 cm above the top of the mudstone. No fossils have been found within this facies. The facies may be distinguished from the other shales of the San Cayetano Formation only in unweathered outcrops.

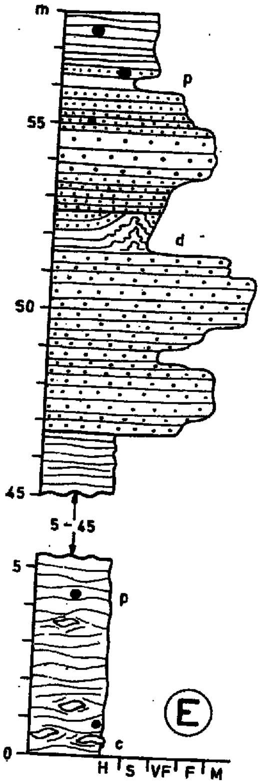


Fig. 9

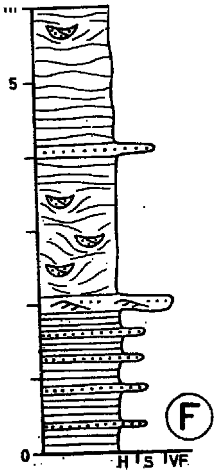
Facies **E**: black shales with pyrite spheres, near locality *1* (cf. Text-fig. 1); legend as for Text-fig. 2

Conditions of deposition. The shales do not reveal any traces of current activity, and they could have settled from suspension. The reducing conditions within the sediment are evidenced by black colour of the shales and the abundance of pyrite spheres. The lack of any evidence of benthic organisms suggests the same conditions for at least near-bottom part of the water body. The septarian nodules are early diagenetic as shown by the deformation of the enveloping shales. The sandy interbeds could have been deposited in the plane bed phase of the upper flow regime, but the inclined bedding with discordant contacts of the laminae requires another explanation. The diapiric structure is an isolated feature related most probably to overpressured conditions within the mud. These conditions could be related to the presence of methane originating from the decay of organic matter (*cf.* Hedberg 1974).

Depositional environment is discussed together with that of the facies *F*.

FACIES F: LAMINATED BLACK SHALES WITH SANDSTONE RIPPLES

The facies was investigated in the bed of the first major stream east of the Pinar del Río — Vinales road (long. 83°41′38″ W, lat. 22°32′07″ N; near locality *17* in Fig. 1). The shaly series is exposed here in a relatively large, discontinuous outcrop. The features observed were compiled into one idealized sequence (Fig. 10).



Description. The sequence consists of black shales with well developed lamination (Pl. 3, Fig. 3). The laminae from one millimeter to a few centimeters thick are distinguishable due to the material and colour differentiation. Silty and sandy laminae are of lightly lighter colour. Distinct beds of very fine-grained sandstones and siltstones with ripple- and flaser-bedding occur rarely. Septarian nodules as well as pyritic spheres are absent. Isolated sandy ripples deformed by sinking are common within the shales (Pl. 3, Fig. 4). In the weathered outcrops the facies may be indistinguishable from other shales of the San Cayetano Fm.

Conditions of deposition. The black shales are probably of the same origin as in the facies *E*. The currents capable of transporting some amounts of sand in form of small ripples occurred occasionally. The muddy bottom was soft enough to permit the sinking of isolated ripples.

Fig. 10

Facies F: laminated black shales with sandstone ripples; section compiled near locality *17* (cf. Text-fig. 1); legend as for Text-fig. 2)

Depositional environment. The facies *E* and *F* have supposedly originated in similar conditions. These most likely have occurred in extensive lagoons with restricted circulation but with large amount of decaying organic matter subjected to mineralization by a bacterial activity (*cf.* Oppenheimer 1960). The lamination in the facies *E* indicates a frequent moderate activation of the water mass by (?tidal) currents or by wind action. The sandy inclusions may have been deposited by stormy waves overtopping barrier islands and moving some quantities of sand over plastic mud bottom, where they sunk after the movement had stopped. The fossil examples of such lagoonal deposits are poorly known (*cf.* Reineck & Singh 1973, p. 354). Two formations described by Broekman (1973, 1974) from the Pliocene of Greece and the Lower Triassic of Germany are interpreted in this way and display some analogies with the facies *F*. The sandy inclusions in the facies *E* display bedding similar to that occurring in tidal deltas.

The similar conditions may have occurred within extensive lakes with occasional flood influxes of silt, very fine sand and abundant organic matter. Other environments in which both or one of the facies discussed could have developed are those situated off the littoral zone in an area with restricted or none bottom circulation, where mud rich in organic matter could settle e.g. from a nepheloid layer, and where gravity-induced sediment transport and deposition did not occur. Such conditions could exist in some parts of outer shelf or upper slope and in isolated bottom areas of a complex continental borderland.

FACIES G: RHYTHMIC SANDSTONES AND SHALES WITH GRADED AND RIPPLE BEDDING

The type section (Fig. 11) was measured in the well known road cut, 13 km from La Palma to Viñales (long. 83°39′30″ W, lat. 22°43′11″ N; locality 5 in Fig. 1).

Description. The section consists of repeatedly interbedded very fine-grained sandstones, siltstones and shales (Pl. 4, Fig. 1). The beds 10 to 20 cm thick are the most common. The lower parts of sandy layers are frequently graded. Lower surfaces of graded beds are commonly deformed into polygonal patterns of load casts. In a few cases flute casts, groove casts and prod casts are preserved on the soles. In the upper parts of the beds ripple and/or flaser bedding occurs, but some beds start with these very structures. Accumulations of plant detritus occur in shaly interbeds. The facies is at least a few tens of meters thick.

Conditions and environment of deposition are discussed together with those of the facies *I*.

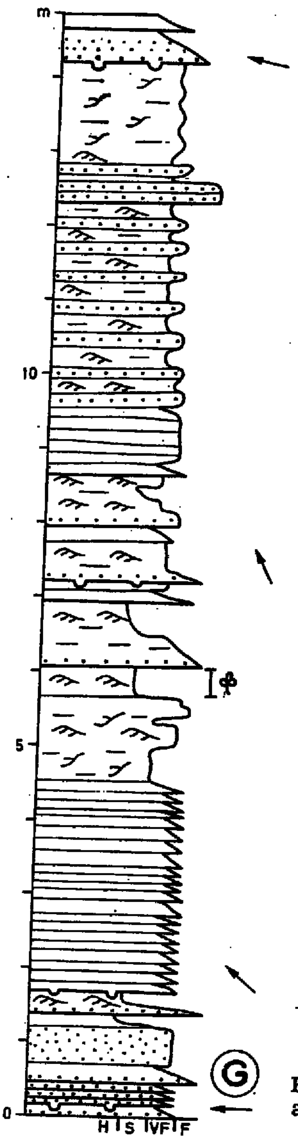


Fig. 11
Facies G: rhythmic sandstones and shales with graded and ripple bedding, locality 5 (cf. Text-fig. 1); legend as for Text-fig. 2

FACIES H: ALTERNATING GRADED SANDSTONES AND SHALES

The type section (Fig. 12) was measured in the vicinity of Cinco Pesos in a cut of the side road branching to the east from the San Cristobal — Bahia Honda road, some 700 m from the branch (long. 83°01′56″ W, lat. 22°46′31″ N; locality *8* in Fig. 1).

Description. The section consists of thin bedded, fairly rhythmic sequence of wacke sandstones up to medium-grained, and shales. The sandstones are commonly graded although some thicker beds consist of homogenous wacke, abounding in plant detritus and mica flakes. A small clastic dike was seen. Rip-up clasts of laminated mud up to 10 cm long are scattered within some sand layers. The basal contacts of the sandstones are erosional. The soles of sandy beds are often deformed into load-casts of various dimensions. The non-load-casted soles are planar or somewhat wavy; on a few of them flute casts and prod casts are visible. The muddy parts of the beds are clearly laminated due to the presence of black laminae rich in plant detritus. In the laminated mudstones wavy structures and convolutions commonly occur.

Within this facies a continuous section, several metres thick, of horizontally bedded black shales was encountered. The shales contain abundant discoidal concretions, 10 to 30 cm in diameter. The concretions are zones of a local interstitial carbonate cementation of the shales; they contain numerous pieces of carbonized wood and other perfectly preserved plant fragments as well as a few undetermined invertebrate fossils. The fossils occur throughout the shales but outside the concretions they are poorly preserved. A more detailed account of the plant fossils will be published separately (Reymanówna & Haczewski, *in prep.*). Conditions and environment of deposition are discussed together with those of the facies *I*.

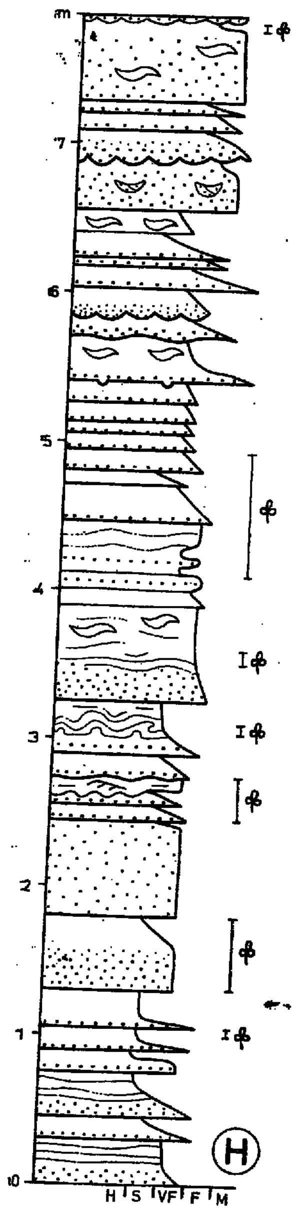


Fig. 12

Facies H: alternating graded sandstones and shales; locality *8* (cf. Text-fig. 1); legend as for Text-fig. 2

FACIES I: THICK BEDDED COARSE-GRAINED CHAOTIC AND GRADED SANDSTONES

The presented sequence (Fig. 13) is an idealized scheme of the highly disturbed section exposed in the vicinity of Cinco Pesos, in a quarry about 1 km east of the facies *H* type-section.

Description. The section consists of coarse-grained, thick-bedded sandstones and relatively thin-bedded sandstones and shales analogous to those of the facies *H*. The thick beds are often graded in their lower parts; some of them begin with pebbly conglomerates or pebbly sandstones containing well rounded quartz pebbles up to 45 mm in diameter. Irregular patches of pebbly sandstone are scattered within the coarser-grained beds. Muddy and sandy rip-up clasts occur in some beds. The basal contacts are erosional. Sole surface are commonly load-casted (Pl. 4, Fig. 3). In the uppermost part of some beds flat intraformational mud pebbles are common, and many of them are armoured with coarse sand (Pl. 4, Fig. 2).

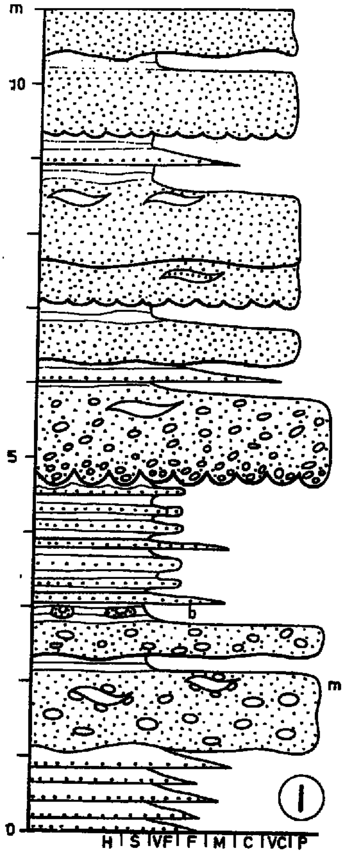


Fig. 13
Facies I: thick-bedded coarse-grained chaotic and graded sandstones, locality *8* (cf. Text-fig. 1); legend as for Text-fig. 2

Depositional processes and environments. All the deposits of the facies *G*, *H*, and *I* may be characterized as flysch facies (*cf.* Dżułyński & Smith 1964). They differ significantly one from the other in structures and textures of sediments.

The facies *G* is characterized by small grain-size, a few erosional structures on the soles of the beds, a volumetrical dominance of the structures related to the tractional transport over graded bedding. Some part of the sediment could have settled from nepheloid layer and then be redeposited by bottom currents as is observed in some present-day continental margins (*cf.* Stanley & Unrug 1972).

The character of the facies *H* is intermediate between normal and proximal turbidites as defined by Parea (*cf.* Walker 1970), while the facies *I* is of proximal character and is comparable with the deposits described as fluxoturbidites (*cf.* Dżułyński & al. 1959, Unrug 1963, Stanley & Unrug 1972).

The abundance of plant detritus within the discussed three flysch facies (*G*, *H*, and *I*) indicates their provenance from redeposition of the river-transported sediments. The facies *H* and *I* were most probably deposited on a submarine fan accumulating at the base of the slope due to channalized transport by turbidity currents and related processes of gravitational subaqueous transport of loose sediments. The facies *H* is spread more widely over the Sierra del Rosario area and may be related to the more distal parts of the fan.

REGIONAL DISTRIBUTION OF THE FACIES

The facies *H* and *I* were encountered only in the Sierra del Rosario and the facies *H* seems to represent the dominant lithology of the San Cayetano Formation in this area. The facies *G* was encountered by the author only in a narow tectonic unit adjoining from NW the limestones of the Ancon tectonic element of Rigassi-Studer (1963). This tectonic unit of an overthrust character is interpreted by Dr. A. Pszczółkowski (*pers. comm.*) as belonging to the region of the Sierra del Rosario. The flysch character of the San Cayetano Formation accords well with this opinion. The deposits of the facies *G* in a similar tectonic position extend to the south-west for about 75 km.

The deposits of the facies *D* occur elsewhere in the Sierra de los Organos in the uppermost part of the formation and constitute the bulk of the San Cayetano Formation in a narow tectonic unit extending to the east and west of San Vicente (northern zone of the Ancon element of Rigassi-Studer, 1963). The facies *A*, *B*, *C*, *E*, *F* are encountered in the remaining part of the Sierra de los Organos. The facies *A* is most commonly observed, the fact that may be due to its greater resistance to weathering and erosion.

ACCUMULATIVE CONTINENTAL MARGIN MODEL

The San Cayetano Formation was deposited in the marginal zone of a continental landmass (Fig. 14). The material was derived from an area built of a monotonous sequence of clastic terrigenous rocks and their metamorphic counterparts. It was transported for a few hundred kilometers (as inferred from the grain-size of sediments, to the extensive, subsiding, seismically active coastal plain, where the river of a low sinusoity course often branched and shifted its course laterally. During floods the fine sediments accumulated on the flood-plain. Some lakes could have existed in interdistributary areas. A delta was prograding built from the material debouched into the sea. The delta was probably strongly affected by the energy of marine environment, not unlike the

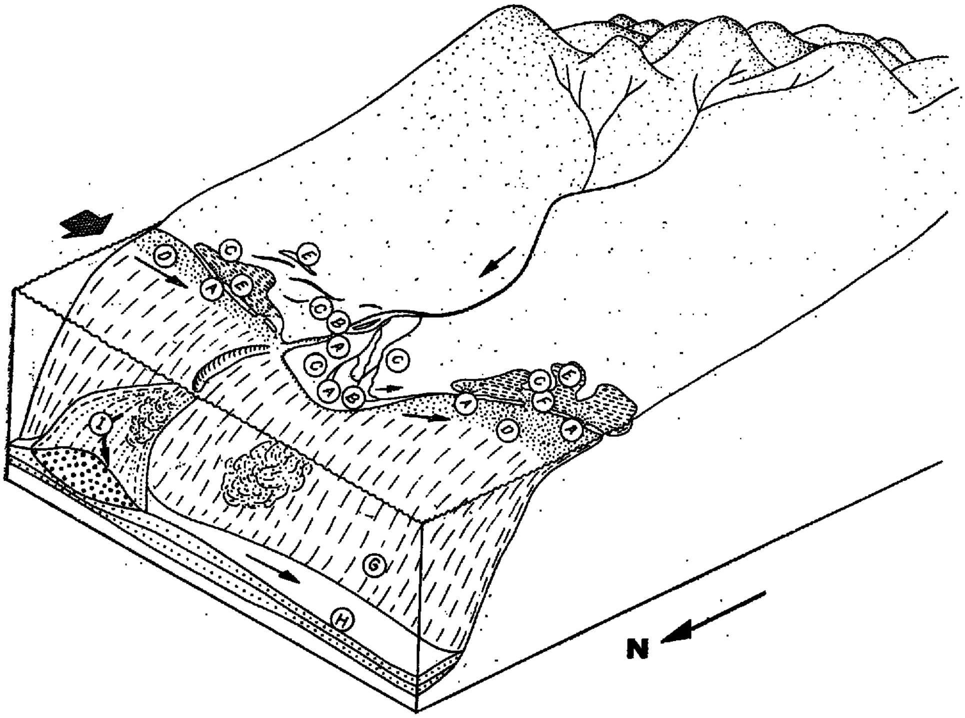


Fig. 14. Hypothetical arrangement of sedimentary environments of particular facies (*A, B, C, D, E, F, G, H, I*) of the San Cayetano Formation
Thin arrows point directions of material transport; checkered arrow marks addition of extraneous material by longshore drift

delta of the Senegal River or even of the San Francisco River in the continous spectrum proposed by Wright & Coleman (1973). The anomalous directions of the currents (diagrams *1* and *2* in Fig. 15) are well explained by the presence of beach ridges deflecting the river course.

The local transgressions caused by compaction and subsidence in the abandoned deltaic lobes, combined with the longshore drift resulted in the formation of barriers and lagoons. The extensive shelf comparable to those of the present continental margins was most probably absent. A large amount of sediments of all size-classes transported by the river were redeposited from the upper part of a continental margin through a submarine valley to the base of the slope onto the submarine fan.

The rapid ceasing of the sediment supply resulted in overall marine transgression. Some barriers could have been eroded during the transgression leaving only the tidal-inlet sequences preserved (*cf.* Kumar & Sanders 1974). Aeolian dunes and beach ridges which are likely to exist in such shorelines could be in most part eroded as they generally have low potential for preservation in geologic record. After the clastic sedimentation had ceased, the deposition of carbonates began which may be interpreted as abandonment facies (*cf.* Elliott 1974) in the Sierra de los Organos area.

PROVENANCE OF SEDIMENTS

The paleocurrent measurements (Fig. 15) were taken mostly from these cross-bedded sandstones of the facies *A* which are interpreted as alluvial plain deposits. They most probably indicate the regional direction of sediment supply to the coastal area. Comparing the diagrams with the geographical distribution of the measurement stations (Fig. 1) it can be realized that the directions from S or SSW predominante in the southern part of the Sierra de los Organos. In the northern part of this region there are many directions from NE that can be attributed to the earlier suggested deflection of the river courses in a nearshore part of the delta. The

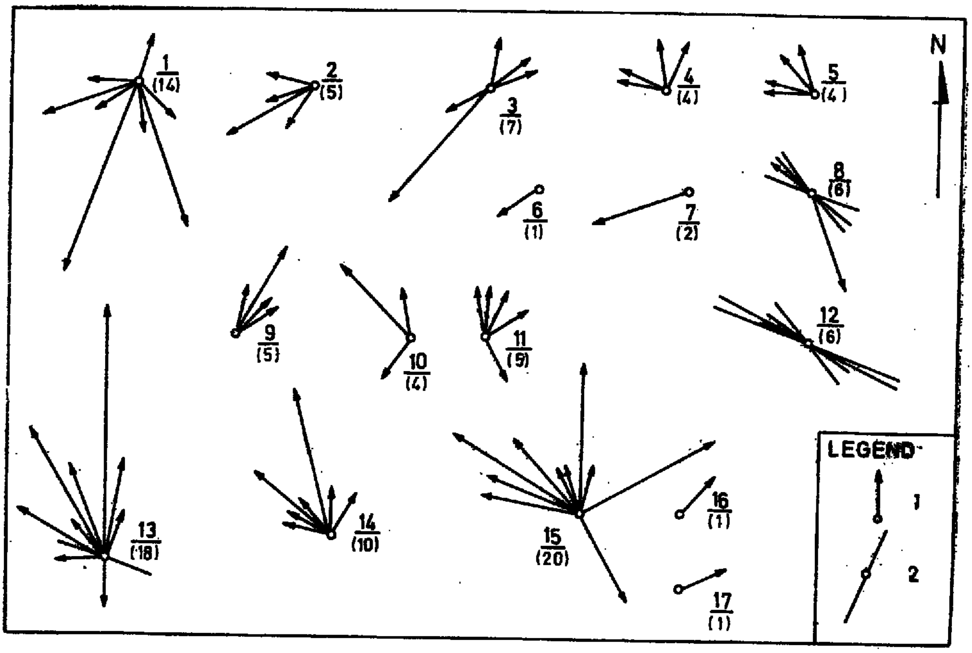


Fig. 15. Diagrams of paleocurrent measurements: localities (*cf.* Text-fig. 1) are indicated by first number accompanying every diagram, number of measurements is given below in brackets

1 azimuth of transport established on hieroglyphs (diagrams *5, 7, 8*) and on cross-stratification in other diagrams; segment length represents one measurement

2 measurement with sense of current not determined, taken perpendicular to ripple crest; length of segment represents one measurement measurements in the section of the tidal channel deposits (Fig. 2b, diagram *3* in Fig. 15) are disposed in two opposing directions reflecting the deposition by ebb and flood currents.

The paleocurrent measurements in the Sierra del Rosario are few and almost half of them was taken on ripples without discernible internal structure and thus are inconclusive as to the sense of the current, but are in good accordance with the current marks and tool marks as to the course. The hieroglyphs indicate dominating directions from SE.

The source of the San Cayetano detritus was most likely south of the area of deposition. Looking to the south of the southern border of the area of occurence of the San Cayetano Formation its metamorphic equivalents are bound on the Isla de Pinos (*cf.* Somin & Millan 1972). These rocks could not be the source of San Cayetano clastics, thus being not valid the opinion expressed by Meyerhoff & Hatten (1974).

It therefore may be concluded that the source area must have been further to the south. Not more than 50 km to the south, behind a continental margin, the deep oceanic Yucatan basin extends. In the search for the lost continent two hypotheses may be taken into acount. The farst is that of Khudoley (*in:* Khudoley & Meyerhoff 1971) and Khain (1975), who postulated the existence of the huge landmass which underwent oceanization after the San Cayetano Formation had been deposited. The oceanization concept is strongly criticised by many authors and alternative solution can be proposed by assuming the continental drift. In this case, the late Palaeozoic orogens of southern Mexico, Guatemala and Honduras could have provided the clastic material to this formation as is suggested by the plate tectonics model of the Caribbean proposed by Uchupi (1973) and Iturralde-Vinent (1975).

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REFERENCES

ALLEN J. R. L. 1967. Computational models for dune time-lag: general ideas, difficulties, and early results. *Sedim. Geol.*, **15** (1), 1—54. Amsterdam.

— & BANKS N. L. 1972. An interpretation and analysis of recumbent-folded deformed cross-bedding. *Sedimentology*, **19** (3/4), 257—283. Amsterdam.

ANKETELL J. M., CEGŁA J. & DŻUŁYŃSKI S. 1970. On the deformational structures in systems with reversed density gradients. *Roczn. P. T. Geol. (Ann. Soc. Géol. Pologne)*, **40** (1), 3—30. Kraków.

BENES K. 1966. Elementos estructurales en la parte central de la formation „San Cayetano". *Revista Technologica*, **4** (3), 7—11. La Habana.

BERMÚDEZ P. J. 1961. Las formaciones geologicas de Cuba. *Geologia Cubana*, No. 1, 177 pp. La Habana.

— & HOFFSTETTER R. 1959. Cuba et îles adjacentes. Lex. Stratigr. Intern., 5, Part 20, 140 pp. Paris.

BROEKMAN J. A. 1973. Sedimentary structures and paleoecology of the Pliocene Kritika Formation in a section near Kalithies (Rhodos, Greece). *Proc. Konikl. Nederl. Akad. Wetensch., Ser. B*, 76 (5), 423—445. Amsterdam.

— 1974. Environmental interpretation of some types of stratification in the Buntsandstein of Lower Saxony and North Hesse (Germany). *Proc. Konikl Nederl. Akad. Wetensch., Ser. B*, 77 (4), 303—316. Amsterdam.

COLEMAN J. M. 1969. Brahmaputra River: channel processes and sedimentation *Sedim. Geol.*, 3 (2/3), 129—239. Amsterdam.

DŻUŁYŃSKI S., & SMITH A. J. 1964. Flysch facies. *Rocz. P. T. Geol. (Ann. Soc. Géol. Pologne)*, 34 (1/2), 246—266. Kraków.

— , KSIĄŻKIEWICZ M. & KUENEN P. H. 1959. Turbidites in flysch of the Polish Carpathian Mountains. *Geol. Soc. Amer. Bull.*, 70, 1089—1118. Baltimore.

ELLIOTT T. 1974. Abandonment facies of high-constructive lobate deltas, with an example from the Yoredale series. *Proc. Geol. Assoc.*, 85 (3), 359—365. London.

HATTEN C. W. 1957. Geologic report on Sierra de los Organos (*Unpub. report; Ministerio de Industrias, La Habana*).

— 1967. Principal features of Cuban geology: Discussion. *Amer. Assoc. Petrol. Geol. Bull.*, 51 (5), 780—789. Tulsa.

HÄNTZSCHEL W. & REINECK H. E. 1968. Fazies Untersuchungen in Hettangium von Helmstedt (Niedersachsen). *Mitt. Geol. Staatsinst.*, No. 37, 5—39. Hamburg.

HEDBERG H. D. 1974. Relation of methane generation to undercompacted shales, shale diapirs, and mud volcanoes. *Amer. Assoc. Petrol. Geol. Bull.*, 58 (4), 661—673. Tulsa.

HOFFMEISTER & al. 1954. Pollen and spores from the Cayetano Formation (*Unpubl. rept.; Ministerio de Industrias, La Habana*).

IMLAY R. W. 1942. Late Jurassic fossils from Cuba and their economic significance. *Geol. Soc. Amer. Bull.*, 53 (10), 1417—1477. New York.

ITURRALDE-VINENT M. A. 1975. Problems in application of modern tectonic hypotheses to Cuba and Caribbean Region. *Amer. Assoc. Petrol. Geol. Bull.*, 59 (5), 838—855. Tulsa.

JÄGER W. 1968. Zur Lithologie, Tektonik und Vererzung im Gebiet von Matahambre (Provinz Pinar del Rio, Kuba). *Jb. Geol.*, 4, 347—385. Berlin.

JOPLING A. V. & WALKER R. G. 1968. Morphology and origin of ripple-drift cross lamination, with examples from the Pleistocene of Massachusetts. *J. Sedim. Petrol.*, 38 (4), 971—984. Menasha.

JUDOLEY [= KHUDOLEY] C. M. & FURRAZOLA-BERMÚDEZ G. 1971. *Geologia del area del Caribe y de la costa del Golfo de Mexico.* 286 pp. La Habana.

KHAIN W. E. 1975. Osnovnye etapy geologischeskogo razvitya Meksikanskogo -Karibskogo regiona. *Trudy Inst. Okeanologii*, 100, 25—46. Moskva.

KHUDOLEY [= JUDOLEY] K. M. & MEYERHOFF A. A. 1970. Paleogeography and geological history of Greater Antilles. *Geol. Soc. Amer. Mem.*, 129, 199 pp. Boulder.

de KLEIN G. V. 1972. Sedimentary model for determining paleotidal range: reply. *Geol. Soc. Amer. Bull.*, 83, 539—546. Boulder.

KORIN I., FINKO W. & KOUTIN P. D. 1973. Geologia i genezis nikelevykh mestorozhdenya v kore vivetrivanya Kuby. In: *Geologia poleznykh iskopaemykh Kuby*, 66—116. Moskva.

KROMMELBEIN K. 1956. Die ersten marinen Fossilien (Trigoniidae, Lamellibr.) aus der Cayetano-Formation West Cubas. *Senckenberg. Leth.*, **37** (3/4), 331—335. Frankfurt. a.M.

— 1962. Beiträge zur geologische Kenntnis der Sierra de los Organos (Cuba). *Zt. Deutsch. Geol. Ges.*, **114** (1), 92—120. Hannover.

KUMAR N. & SANDERS J. E. 1974. Inlet sequence: a vertical succession of sedimentary structures and textures created by the lateral migration of tidal inlets. *Sedimentology*, **21** (4), 491—532. Oxford.

KUTEK J., PSZCZÓŁKOWSKI A. & WIERZBOWSKI A. 1976. The Francisco Formation and an Oxfordian ammonite faunule from the Artemisa Formation, Sierra del Rosario, western Cuba. *Acta Geol. Pol.*, **26** (2). Warszawa.

LEWIS D. W., Van der LINGEN G. J. & JONES D. J. 1970. The construction of a transparent grain-size comparator. *J. Sedim. Petrol.*, **40** (1), 472—474. Menasha.

MCKEE E. D., CROSBY E. J. & BERRYHILL H. L. 1967. Flood deposits, Bijou Creek, Colorado, June 1965. *J. Sedim. Petrol.*, **37** (3), 829—851. Menasha.

MEYERHOFF A. A. 1967. Future hydrocarbon provinces of Gulf of Mexico-Carribean region. *Trans. Gulf Coast Assoc Geol. Soc.*, **17**, 217—260. New Orleans.

— & HATTEN C. W. 1974. Bahamas salient of North America: tectonic framework, stratigraphy, and petroleum potential. *Amer. Assoc. Petrol. Geol., Bull.*, **58** (6), 1201—1239. Tulsa.

OPPENHEIMER C. H. 1960. Bacterial activity in sediments of shallow marine bays. *Acta Geochim. et Cosmochim.*, **19** (4), 244—260. London.

POKRISHKIN V. & SHIROKOV V. 1966. Generalidades sobre la estructura y fosfatizacion mesocenozoica en los sedimentos de la provincia de Pinar del Rio. *Revista Tecnologica*, **4** (4), 20—31. La Habana.

POPLAVSKI I. T. 1966. Estructura geologica del yacimiento Matahambre. *Revista Tecnologica*, **4** (1), 39—52. La Habana.

PSZCZÓŁKOWSKI A. 1971. Jurassic, Cretaceous and Paleogene deposits of Sierra del Rosario (Cuba). *Bull. Acad. Pol. Sci., Sér. Sci. de la Terre*, **19** (4), 249—259. Varsovie.

REINECK H. E. & SINGH I. B. 1973. *Depositional sedimentary environments.* Springer, 439 pp. Berlin.

RIGASSI-STUDER D. 1963. Sur la geologie de la Sierra de los Organos, Cuba. *Arch. d. Sci.*, **16** (2), 339—350. Genève.

SANTRUCEK P. 1972. Geologia de caolines y arcillas en Cuba occidental. *Revista Technologica*, **10** (3/4), 36—65. La Habana.

SIMONS D. B., RICHARDSON E. V. & NORDIN C. F., Jr. 1965. Sedimentary structures generated by flow in alluvial channels. *In:* MIDDLETON G. V. (*Ed.*) Primary sedimentary structures and their hydrodynamic interpretation. *Soc. Econ. Paleont. Mineral., Spec. Publ.* No. **12**, 34—52. Tulsa.

SOMIN M. L. & MILLAN G. 1972. Metamorficheskye kompleksy Pinosa, Escambraya i Oriente na Kube i ikh vozrast. *Izv.* Akad. *Nauk SSSR, Ser. Geol.*, No. 5, 48—57. Moskva.

STANLEY D. J. & UNRUG R. 1972. Submarine channel deposits, fluxoturbidites and other indicators of slope and base-of-slope environments in modern and ancient marine basins. *In:* RIGBY J. K. & HAMBLIN W. K. (*Eds*), Recognition of ancient sedimentary environments. *Soc. Econ. Paleont. Mineral., Spec. Publ.* No. **16**, 287—340. Tulsa.

de la TORRE A. 1960. Fauna de la formacion Cayetano del Jurassic Medio de Pinar del Rio. *Soc. Cubana Historia Nat. Mem.*, **25** (1), 65—72. La Habana.

UCHUPI E. 1973. Eastern Yucatan continental margin and western Caribbean tectonics. *Amer. Assoc. Petrol. Geol. Bull.*, 57 (6), 1075—1085. Tulsa.

UNRUG R. 1963. Istebna beds — a fluxoturbidite formation in the Carpathian flysch *Rocz. P. T. Geol. (Ann. Soc. Géol. Pologne)*, 33 (1), 49—92. Kraków.

VAKHRAMEYEV V. A. 1965. First discovery of Jurassic flora in Cuba. *Paleont. Zhur.*, No. 3, 123—126.

— 1966. Primer descubrimiento de flora del Jurassico en Cuba. *Revista Tecnologica*, 4 (2), 22—25. La Habana.

WALKER R. G. 1970. Review of the geometry and facies organization of turbidites and turbidite-bearing basins. *In:* LAJOIE J. (*Ed.*) Flysch sedimentology in North America. *Geol. Assoc. Canada, Spec. Papers No.* 7, 219—251.

WIERZBOWSKI A. 1976. Oxfordian ammonites of the Pinar del Río province (western Cuba); their revision and stratigraphical significance. *Acta Geol. Pol.*, 26 (2). Warszawa.

WRIGHT L. D. & COLEMAN J. M. 1973. Variations in morphology of major river deltas as functions of ocean wave and river discharge regimes. *Amer. Assoc. Petrol. Geol. Bull.*, 57 (2), 370—398. Tulsa.

G. HACZEWSKI

RECONOCIMIENTO SEDIMENTOLOGICO DE LA FORMACIÓN SAN CAYETANO: MARGEN CONTINENTAL ACUMULATIVO EN JURASICO DE CUBA OCCIDENTAL

(Resumen)

Litología de la Formación San Cayetano (Fig. 1) es muy variada tanto verticalmente, como lateralmente. Se distinguen nueve facies (Fig. 2—13 y Lam. 1—4): *A* — areniscas con estratificación entrecruzada en gran escala, *B* — areniscas con estratificación entrecruzada en escala media y pequeña *C* — limolitas y lutitas con estratificación ondulitica y flaser, *D* — limolitas y areniscas con ondulas de oscilación y estratos conchiferos, *E* — lutitas negras con concreciones piriticas, *F* — lutitas negras laminadas con lentes de areniscas, *G* — estratos finos y alternados de areniscas y lutitas con estratificación graduada y lenticular, *H* — flysch en estratos finos con abundantes detritos vegetales, *I* — estratos de considerable espesor de areniscas de grano grueso y conglomeraticas con guijarros lutiticos.

En la Sierra de los Organos predominan sedimentos de una llanura costera aluvial (Fig. 14) depositados por un río, que arrastraba material desde el sur algunos cientos de kilometros (Fig. 15). Una parte de los depositos formó una delta, otra parte fue redepositada por corrientes paralelos a la costa y por corrientes turbiditicos. En la Sierra del Rosario la Formación San Cayetano presenta sedimentos de tipo flysch con manifestaciones limitadas del flysch proximal. Margen continental acumulativo existia debido a una continua subsidencia. La interrupción total del suministro del material clastico se reflejó en la transición de los depositos de la Formación San Cayetano a las calizas.

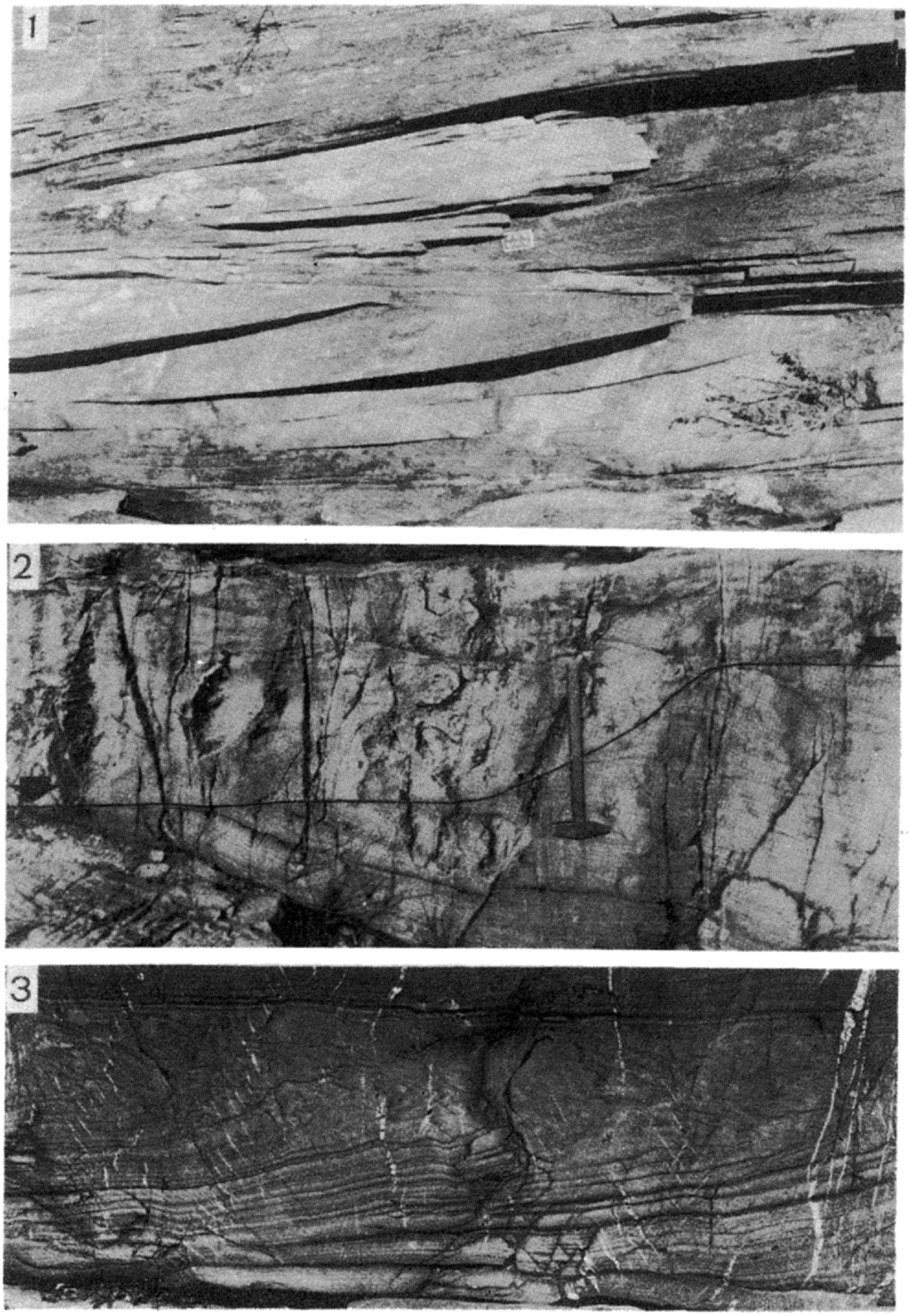
G. HACZEWSKI

WSTĘPNE BADANIA SEDYMENTOLOGICZNE FORMACJI SAN CAYETANO ZACHODNIEJ KUBY

(Streszczenie)

Przedmiotem pracy jest analiza zespołu cech sedymentacyjnych formacji San Cayetano zachodniej Kuby. W zbadanych profilach (*por.* fig. 1) wyróżniono 9 facji (por. fig. 2—14 oraz pl. 1—4), rozważając ich warunki hydrodynamiczne oraz środowisko sedymentacji. Interpretację oparto na niezależnej analizie poszczególnych facji, gdyż ich przedtektoniczna pozycja nie jest znana. W Sierra del Rosario występują utwory o cechach fliszu, zaś w Sierra de los Organos osady płytkomorskie i aluwialne. Sedymentacja odbywała się na obszarze akumulacyjnej krawędzi kontynentalnej o stałej i powolnej subsydencji; składały się na nią osady równi aluwialnej, delty, przybrzeżnych barier i lagun, płytkiego morza, oraz stoku podmorskiego i podmorskich stożków (por. fig. 14—15). Materiał donoszony był przez rzekę z odległości kilkuset kilometrów z południa, zaś z obszaru deltowego był on redeponowany przez prądy przybrzeżne i prądy zawiesinowe. Obszar źródłowy osadów formacji San Cayetano znajdował się przypuszczalnie w rejonie obecnej Ameryki Środkowej, oddzielonej od obszaru zachodniej Kuby oceanicznym Basenem Jukatanu powstałym po osadzeniu badanej formacji.

Exposure of facies *A* (locality *3*) in vicinity of Punta de Sierra

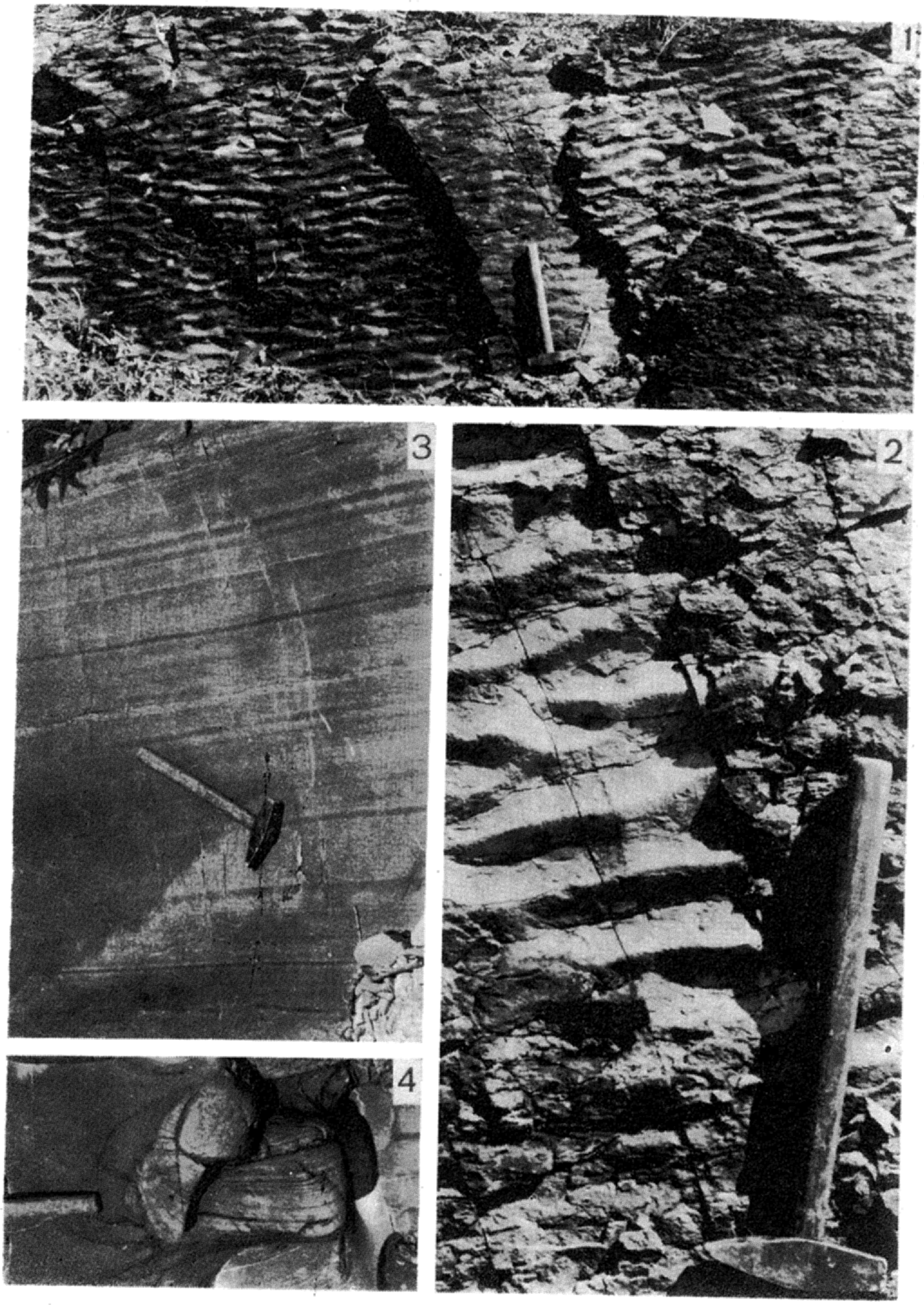


Sedimentary structures in sandstone facies (*A*)

1 — Large scale cross-lamination in type section (grain-size comparator 8 cm long)

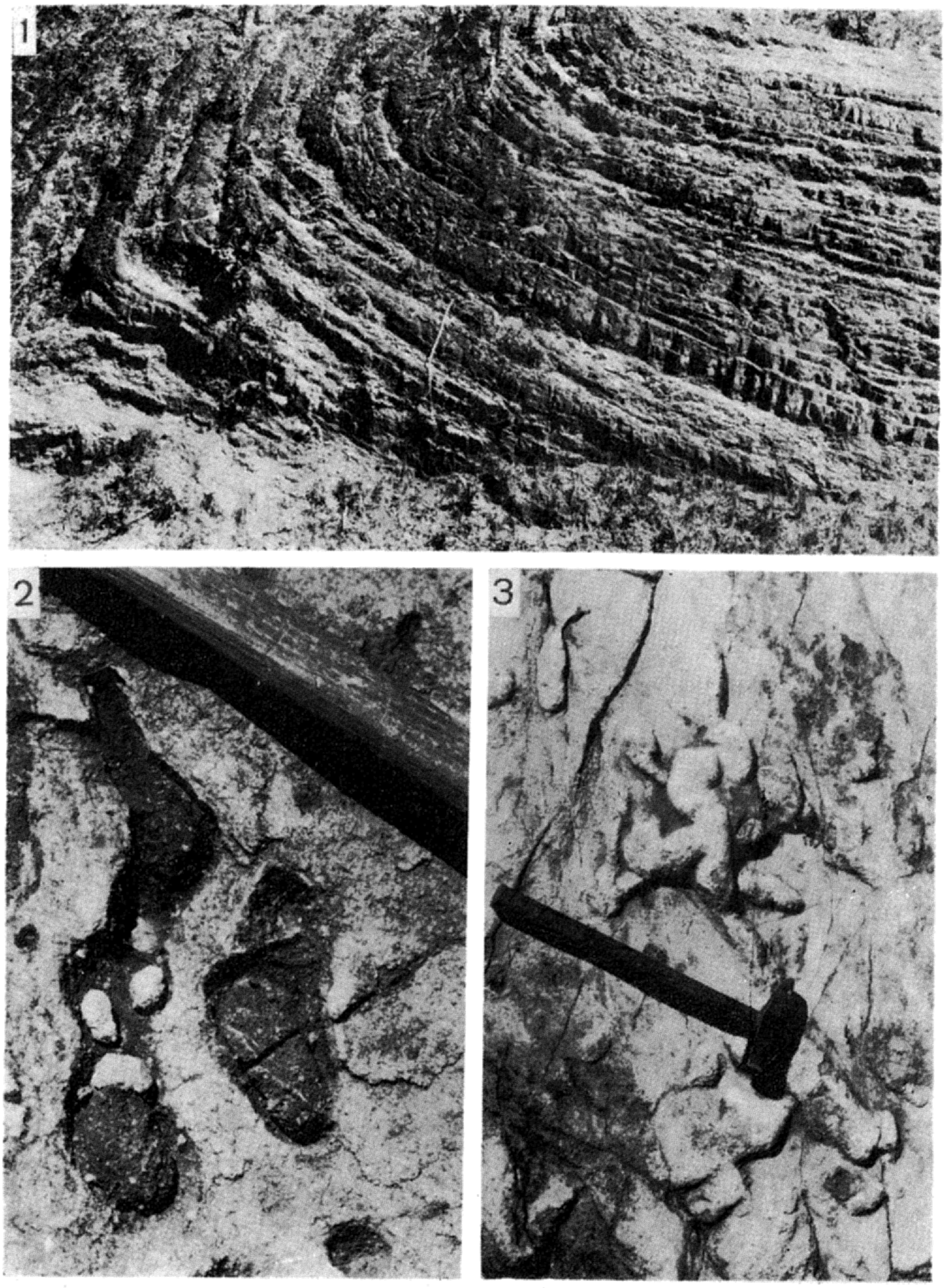
2 — Erosional channel (arrowed) in the set of deformed cross-laminae (hammer 40 cm long); locality *15*

3 — Deformed cross-stratification with obliteration of laminae (the bed is 40 cm thick); locality *17*



Sedimentary structures in muddy facies (*D* and *F*)

1 — Oscillation ripples in facies *D* (hammer 40 cm long); locality *21*
2 — Close-up view of the preceding exposure (after cleaning; arrowed in Fig. 1)
3 — Laminated black shales; type section of facies *F*
4 — Isolated sunken ripple in shales; type section of facies *F*



Sedimentary structures in flysch facies (*G* and *I*)

1 — Type section of facies *G* (the beds are overturned)
2 — Armoured mud balls at the top of proximal turbidite bed; type section of facies *I*
3 — Load-casted hieroglyphs on the sole of proximal turbidite bed; type section of facies *I*