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Použití mikropaleontologie v inženýrské geologii

Rozvoj inženýrské geologie a stoupající nároky na spolehlivost inženýrskogeologického výzkumu při řešení praktických úkolů ve stavebnictví si vynutily pokrok pracovních metod a hlubší zkoumání zejména v oboru usazených hornin. Správná interpretace jednotlivých sedimentačních celků a jejich složek vyžaduje pečlivé sedimentárně petrografické a mineralogické výzkumy, o které by se opíraly závěry genetické, paleogeografické a stratigrafické. Moderní mikropaleontologie přispívá k těmto otázkám závažnými daty.

Při zakládání staveb se dostáváme do styku s velmi různorodými a různě uloženými sedimentárními horninami, do nichž se přenášejí napětí vyvozovaná stavebním dílem. Odlišný charakter má inženýrskogeologický výzkum ve zpevněných sedimentech, který používá při řešení inženýrskogeologických úkolů běžných metod technické sedimentární petrografie a mechaniky hornin, na rozdíl od specifického výzkumu v nezpevněných soudržných a nesoudržných zeminách, jenž se opírá o litologicko-faciální rozbory a mikrobiostratigrafické studie v úzké spolupráci s mechanikou zemin.

Zvláštní pozornosti zasluhují marinní pelitické sedimenty mezozoika a hlavně terciéru, které poskytují základové půdy velmi proměnlivých fyzikálně mechanických vlastností. Inženýrskogeologický výzkum soudržných zemin musí být především účelově zaměřen na objasnění jejich fyzikálně mechanických vlastností z hlediska stavebního. Tomuto zaměření je třeba přizpůsobit i metodiku výzkumu. Kromě základních mineralogicko-petrografických metod je účelné používat i studia mikropaleontologie spolu s mikrolitologií a mnohých speciálních metod fyziky, mechaniky, fyzikální chemie i geochemie, které napomáhají zjišťování fyzikálních, mechanických, fyzikálně chemických i chemických vlastností, a určují tak chování zeminy v souvislosti se stavebním dílem. Pečlivé studium těchto vlastností je považováno za jeden z rozhodujících úseků dalšího vývoje inženýrské geologie.

Technické vlastnosti soudržných zemin úzce souvisejí především s jejich genezí, minerálním i chemickým složením, texturou, strukturou a stratigrafickým zařazením, tj. stářím. Tyto vlastnosti charakterizují petrografický typ horniny, který je podmíněn okolnostmi vzniku a procesy vývoje. Při průzkumu soudržných zemin je třeba věnovat pozornost hlavně komplexní sedimentární petrografické analýze minerálního složení i obsahu horninotvorných organismů, které přispívají k objasnění správné představy o původu a stáří hornin. Sedimentologicko-mikropaleontologické rozbory umožňují zařazení soudržných zemin do základních petrografických typů, které jsou začleněny podle biostratigrafické příslušnosti do faciálně genetických komplexů určité geologické formace.

Určení petrografických typů soudržných zemin má velký význam i z inženýrskogeologického hlediska. Je základem pro inženýrskogeologickou klasifikaci hornin, která se opírá o studium fyzikálně mechanických vlastností zkoumaných běžnými metodami mechaniky zemin. Půdně mechanickými roz-

Contribution to the information on the geological development and structure of Cuba and the Caribbean region

(3 text-figs.)

OTAKAR KUMPERA[1]—VLADIMÍR ŠKVOR[2]

Abstrakt. V práci je podán přehled geologického vývoje Kuby a vysvětleny jeho vztahy ke karibskému prostoru. Celá oblast má výraznou blokovou stavbu. Rozhodující význam pro tektonické, magmatické a sedimentační pochody má soustava strukturních švů, které provázejí rané stadium karibské geosynklinály.

Introduction

The geological development of island chains is a problem that draws attention not only because of interesting geological phenomena but also because of information useful in the analysis of the development of older and more mature geotectonic units of the earth's crust. But modern geological mapping, based on the uniform set of detailed geological and geophysical maps, is still lacking in most of these areas. The same may also be said of Cuba, where the authors made their studies, and the whole Caribbean region; papers as yet published on the geological structure may be based solely upon partial areas and profiles. The present paper gives an original concept of the geological structure and the development of Cuba and the whole Antilles. The authors' idea was conceived on the basis of so far published geological and geophysical reports and own studies made in some parts of Cuba.

Survey of the geological development

Regionally metamorphosed rocks of the so-called basal complex (J. Butterlin 1956) are regarded as the oldest rocks of Cuba and the whole Antilles. They crop out in three large areas: on the east of the Province Oriente, in the Escambray Mountains and in the island Isla de Pinos. The rock complexes are formed of phyllites, crystalline limestones, mica schists and scarce gneisses; the initial rocks are frequently of pyroclastic origin. There is still no palaeontological evidence of this complex; most authors state that the original rocks are Jurassic in age but some others suppose that they are Palaeozoic in age.

The complex is overlain unconformably by a palaeontologically evidenced Upper Cretaceous.

Microstructure and macrostructure of the metamorphites are the features that helped to discern for certain this complex from its unconformably overlying beds. This fact proves that the metamorphites were subject to different geological processes of different structural plan.

The studies made by one of the authors (V. Š.) in the eastern part of the Province Oriente and partly in the Sierra de Escambray indicate that these rocks are metamorphosed in green schist and amphibolite facies. Recent laboratory examinations have revealed that the amphibolite facies requires a temperature not less than 450 °C. This is the temperature which may be

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expected during metamorphic processes at a depth of about 3,000 metres (V. Škvor 1965).

The mica schists of the metamorphic complex could approach the surface only if overlying beds 3,000 metres thick had been removed. In Cuba, such a removal must have taken place in times preceding, but not later than, the Upper Cretaceous. Besides, if taken geologically, considerably long time is necessary to remove a complex 3,000 metres thick. Another precondition must have been satisfied for the origin of the mica schists: rock complexes had been laid down in times preceding the metamorphic processes affecting these rocks at a thickness exceeding at least 3 km. It should be noted that the metamorphic process itself is not a short process either. With a view to the time elapsed necessarily during all these processes, the authors assume that the original rocks of the basal complex formed in Palaeozoic times.

Palaeontologically evidenced is the remarkable and thick flysch complex San Cayetano, which rises in the western part of the island. It is believed that the fauna and flora gained from it is Lower to Middle Jurassic in age. Ammonites and tintinnids date more closely the Upper Jurassic, which is largely found in a carbonate development. The sedimentation of Upper Jurassic is continuously followed by the carbonate sedimentation of Neocomian age (N. M. Herrera 1961).

Apparently in Aptian and Albian times began an intense volcanic activity (R. H. Palmer 1945, L. M. R. Rutten 1936), the result of which strongly affected further development of the island. An extensive volcanic belt, which developed in the central part of Cuba, is formed of thick accumulations largely of andesite composition and their tuffs with intercalations of limestones and sandstones (so-called tuffaceous series ranging in age from Aptian? to Turonian). In the areas beyond volcanic activity limestones and transitional volcano-sedimentary facies were laid down (G. Furrazola et al. 1964).

First orogenic movements took place at the end of the Turonian (R. W. Imlay 1944, J. Buterlin 1956). Upper Turonian and Senonian beds are therefore widely differentiated in facies development, thus comprising even diastrophic facies, and rest on older beds with apparent unconformity. The orogenic unrest of Cretaceous age is associated with intense magmatic intrusive activities (L. M. R. Rutten 1940, W. P. Woodring 1954, P. J. Bermudez 1959 et al.). It is probable that in the Upper Cretaceous, bodies of ultrabasic and basic intrusive rocks forming discontinuous belts reached the surface along the northern coast of the island. At the same time bodies of granodiorites and quartz diorites were lifted in the area of volcanic accumulations, especially in central Cuba.

One of the most significant phenomena of the Paleogene history of Cuba is the origin of an extensive volcanic belt in the area of the Sierra Maestra Mountains, on the east of the island. It consists of the very thick volcanic and volcano-sedimentary complex El Cobre, largely of Palaeocene and Lower Eocene age (S. Taber 1931, P. J. Bermúdez — R. Hofstetter 1959). In petrographical and geological composition the belt is analogous to the volcanic belt of Cretaceous age in central Cuba. Elsewhere is the lower part of the Paleogene clastic and limestone in character (P. J. Bermúdez 1937, 1950, J. F. de Albear 1947). Clastic sedimentation was strongly rejuvenated especially in the central part of the island in Eocene times, when a Paleogene tectonic unrest attained its maximum intensity during so-called Cuban folding. Eocene in age are also the bodies of acid intrusive rocks, mostly quartz diorites, which penetrate into the

Paleogene complex El Cobre in the Sierra Maestra Mountains (S. Taber 1934, R. C. Mitchel 1953).

Higher up, in the Paleogene complex, the clastic sedimentation suddenly ceased and the limestones sedimentation gradually prevailed (P. J. Bermúdez 1950, P. J. Bermúdez — R. Hofstetter 1959). Contemporaneous fold deformations were becoming less expressive, and so Oligocene sediments are slightly undulated. These tendencies are also apparent in the lower part of the Miocene, in which dominant rocks are the limestones forming folds having a very small amplitude and a high radius of curvature (G. Furrazola et al. 1964).

First indications of emergence above the water level may be observed as early as the Oligocene but the main uplift took place in the Late Miocene (P. J. Bermúdez — R. Hofstetter 1959). Sediments of the upper part of the Miocene, mainly the clastics, were laid down only in places close to the present shore. Uplifting continued on also in Pliocene and Quaternary times, when Cuba and numerous surrounding islands were given gradually present outlines and their morphology was shaped, as evidenced by the relics of terrace levels (J. J. Corral 1945).

Main features of the geological structure

The island itself is about 1,200 km long and on the average 90—100 km wide. A distinctly linear outline of Cuba is controlled by two directions which intersect in the Province Habana. The eastern, major part of Cuba has a longitudinal axis striking ESE—WNW (110°), the western part is elongated toward NE—SW. The southern boundary of the eastern part of Cuba (Province Oriente) and the highest mountains, Sierra Maestra, trend about west-east. The two, and/or three, directions as given above characterize in main principal outlines of Cuba, being apparent in detailed division of this island and its principal geographical forms. These directions are not incidental since even a preliminary consideration will reveal that they are controlled by the geological structure. Such a conclusion is in full agreement with published geological and geophysical maps. It is apparent from the brief survey of the geological development that the island is divided into areas having (1) complete and incomplete stratigraphical development and (2) older metamorphosed rock massifs which reach the surface. It is beyond any doubt that the division is not incidental, being controlled by the whole structure and geological development of the island. Geological and geophysical papers evidently show longitudinal and transverse structures which divide the whole Cuba into several more or less independent blocks. It is now possible for the authors to distinguish from these papers longitudinal structures as follows: along the northern coast extends a belt 20—30 km wide that is accompanied by the occurrences of ultrabasic rocks. Peridotites, harzburgites, dunites and other ultrabasic rock types are serpentinized to a various degree. In the Province Oriente these rocks form homogeneous massifs. In the other parts of the Island they form smaller bodies usually penetrating into surrounding sediments. The direction of the belt is roughly coincident with the geographical boundaries of the island. Like the outline of the island, the belt in the Province Habana changes to NE—SW and follows this trend in the Province Pinar del Rio. The whole belt is interrupted by some transverse depressions filled with young deposits. Some disagreement exists regarding the age of the ultrabasic rocks discussed by several authors. In the Province Pinar del Rio the ultrabasic rocks are known to cross the Jurassic;

in the central part of the island, the Cretaceous. Some authors (R. H. Palmer 1945, R. C. Mitchell 1955) report the ultrabasic rocks crossing the rocks of Eocene, and even Miocene, age. Spectral analyses of some samples of older metamorphosed sediments proved increased amounts of Cr, Ni, and Co, thus indicating the presence of ultrabasic rocks in a supply area. In addition to the occurrence of ultrabasic bodies, the longitudinal belt is characterized by the large accumulation of sediments mainly of Cretaceous age ranging in thickness from 5 to 8 kilometres. Gravimetrically and magnetometrically, the belt produces expressive minima. This phenomenon, which contradicts physical properties of the ultrabasic igneous rocks, is explained by O. N. Solovev et al. (1964b) having been caused by a downthrow of the heavier lower structure along the whole belt and by a subsequent filling of this area with lighter sediments. According to O. N. Solovev, the ultrabasic bodies occupy only a small part of that area and modify the complete gravimetrical picture merely in detail. Essentially the belt under consideration is a large graben set along a depth suture, which had formed original channels for ultrabasic igneous rocks.

South of the longitudinal belt is a wide area roughly coincident with the Cretaceous volcanic belt of central Cuba which builds up most of the insular area. Nonvolcanic sediments forming part or the cover of the volcanic complex are here reduced and their thickness is of the order 2—4 km. Gravimetrically, this area is positive, and it is possible to deduce here the elevation of a lower structure. In the central part of the island, massifs of metamorphosed rocks and granitoids crop out. The granitoids are largely composed of basic types. Acid derivates are scarce. Granitoid accumulations are mostly confined to the southern border of the graben mentioned above.

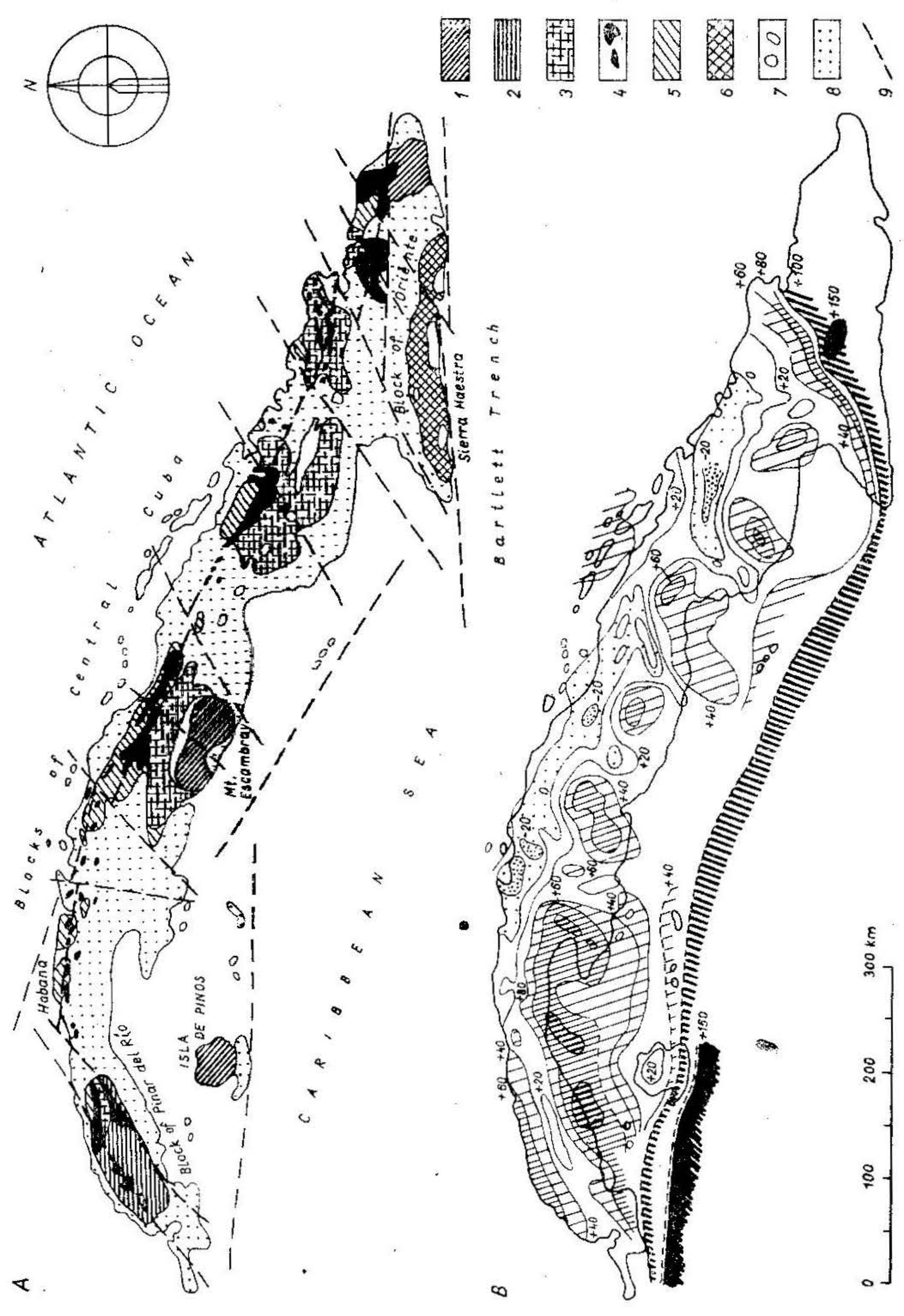
Other longitudinal structures stretch also along the northern and southern margin of central Cuba with many islands of various extent. The shore inundated by a shallow sea up to a distance of 30—40 kilometres represents a littoral zone with a long-lasting slight subsidence. The accumulation of Cretaceous and Tertiary sediments attains here a relatively great thickness.

No less important structures in the geology of Cuba are those trending approximately NE—SW. Associated with ultrabasic rocks in Pinar del Rio, a zone of gravimetrical minimum is roughly of the same trend. Other transverse structures are evidently shown in a geological map by the depressions filled with young sediments, gravimetrically producing also prominent minima. Of principal transverse structures, the following lines are particularly noteworthy: the line trending southeast of Bahia de Santa Clara, the line Yatibonico—Tunas de Zora, the line Cayo — Safinal — Camaguey, and the well-known line Cabo Cruz — Bahia de Nipe (which separates geologically the Province Oriente from other parts of Cuba).

Transverse and longitudinal structures are conditioned by big faults as shown in geological and geophysical patterns. They divide the whole island into several blocks with more or less independent geological development (Fig. 1).

Fig. 1A. Scheme of the principal block structure of Cuba. Modified from geological map by A. Núnez Jimenez et al. (1962)

Fig. 1B. Scheme of the gravimetric situation (modified from O. N. Solovev et al. 1964b). *1* — basal complex; *2* — Jurassic rocks; *3* — Cretaceous volcanic rocks; *4* — ultrabasic rocks; *5* — Cretaceous sediments; *6* — volcanic rocks of Paleogene period; *7* — granitoids; *8* — Cenozoic sediments; *9* — main deep faults


A
B
ATLANTIC OCEAN
Blocks of Central Cuba
Habana
Block of Pinar del Río
ISLA DE PINOS
CARIBBEAN SEA
Mt. Escambray
Block of Oriente
Sierra Maestra
Bartlett Trench
N
1
2
3
4
5
6
7
8
9
0
100
200
300 km

In geological past some blocks were relatively uplifted and removal or stratigraphical starving took place there. In Pinar del Rio, Isla de Pinos, Escambray Mts., and eastern Oriente, both the Jurassic and the older metamorphosed rock complex crop out; the latter may be regarded as part of the lower structure of the island. In the course of geological history individual blocks had a relatively different mobility. Therefore, thicknesses and facies development of sediments of the same age in neighbouring blocks are sometimes different. Deep faults bounding single blocks often served as supply channels for volcanics.

Rock complexes are folded in individual blocks to a various degree. Most prominent fold structures may be expected especially at the margins of the blocks, i. e. where the relative movements equalized and free room could be formed. Intense folding occurred also in the above longitudinal graben: the sediments were deposited in a mobile zone between two stable blocks and even relatively slight movements must have been strong enough to produce intense fold deformations.

The Province Oriente, compared with other regions of Cuba, underwent a rather different geological development. Almost throughout Cretaceous and Jurassic times the large part of Oriente was a dry land, and rock massifs were removed. So the old heavier lower structure approached the surface and the whole province now displays relatively gravimetrical maxima. Of interest is the different development of ultrabasic rocks along the above longitudinal structural suture. Whereas in most areas of Cuba the ultrabasic rocks largely form a set of apophyses cutting through folded sediments, in the block of Oriente these rocks build up big homogeneous massifs (M. I. Kozary 1956, G. Furrazola et al. 1964). The authors of this paper believe that the difference in entire morphology and the position of ultrabasic massifs in Oriente may be explained by uplifting and stratigraphical starving of the whole area before ultrabasic rocks had ascended. In this province ultrabasic rocks cutting along a longitudinal fault were not scattered into folded sediments but, passing through a relatively massive lower structure, they probably reached almost the surface forming here laccoliths or extrusions.

Contrary to all areas of Cuba, the big structure Sierra Maestra has a special position on account of different trend. The whole mountain chain extends west — eastward for more than 200 kilometres along the southern border of the Province Oriente and at the shore it steeply dips along a fault scarp into the deep Bartlett Trough. Nonvolcanic sediments are scarce. The Sierra Maestra Mountains largely consist of eruptive rocks of various types — andesite porphyrites, basalts, melaphyres, tuffs and volcanic agglomerates. In Paleogene times granodiorites and quartz diorites ascended into upper parts. Still further west, the whole mountains continue as the submarine ridge Cayman and are set along a series of deep westeastward faults forming supply channels for igneous rocks. After eruptions had ceased the whole block was uplifted. At present it has an alpine relief and is subject to intense erosion.

Geological relations to adjacent areas

Cuba is the largest island among the Antilles which form a conspicuous insular chain between North and South America more than 3,000 km long. It consists of the Greater and Lesser Antilles, which differ in geological development (C. Schuchert 1935, A. J. Eardley 1951, W. P. Woodring 1954). The islands of Greater Antilles are similar in structure to Cuba, with dominant Cretaceous

or Tertiary magmatites and mainly carbonate sediments. The outer, so-called limestone Lesser Antilles are essentially analogous to the Greater Antilles. The inner, volcanic Lesser Antilles are formed only of volcanic rocks ranging in age from Eocene or Oligocene to Recent. As compared with the other islands, the volcanic Lesser Antilles have so far produced a more intense mobility evidenced by strong seismicity and volcanic activities.

North of the Greater Antilles, Bahame Shoal is composed of flat-lying carbonates of Cretaceous to Quaternary age having up to 5 km in thickness. On the NW and W, in Florida, similar carbonates are found.

Stretching north and east of the Lesser Antilles is the Atlantic ocean with a geophysically proved oceanic crust. On the south, the chain of the Lesser Antilles is connected with the Venezuelan and Columbian Andes. Both are covered by a thick Palaeozoic and contain Palaeozoic instrusions, which were later overlain by Mesozoic and Tertiary sediments of considerable thicknesses. Principal structures running toward the Caribbean sea at the margin of the continent are truncated mostly by a fault.

South of the islands Antilles is the Caribbean sea, which separates the Isthmus of Panama from the Pacific ocean. It is worth noting that axes of Palaeozoic structures in Quatemala and Honduras run perpendicular to that isthmus toward the Caribbean sea (H. Stille 1942, A. J. Eardley 1951). The Isthmus of Panama largely consists of the volcanic rocks with basalt and andesite ranging in age from Eocene to Quaternary. In Miocene times folding was accompanied with the ascent of granitoids.

Considerations on the geological history of the Caribbean sea result in hypotheses which are based on meagre data. At a glance it is evident that dissection in depth of the Caribbean sea is the most prominent feature. Apart from a relatively narrow shelf at the coast of South America, extending northerly as far as the Leeward Islands, and the shelves close to insular belts, the whole region is divided into two parts. Both are separated from each other by an extensive submarine elevation which runs between Honduras, on the one hand, and Jamaica, Haiti and Puerto Rico on the other. The ridge covers an area of a relatively shallow sea with the shoals Mosquito, Rosalinda, Pedro and Serranilla less than 200 metres deep. The Tanner depression, lying east of that elevation, is also divided by two submarine ridges. The southwestward ridge Beata is virtually continuation of the peninsula Pedernales toward Haiti. West of the Lesser Antilles is the elevation Aves containing several submarine extinct volcanoes, parallel with a number of active volcanoes in the Lesser Antilles (H. H. Hess — J. C. Maxwell 1953). The ridge Beata divides the Tanner depression into two parts: the Venezuelan depression on the east (with a depth of as much as 6,000 metres) and the Columbian depression on the west (with maximum depth of about 5,000 metres). Still more dissected is the marine space north of the ridge Honduras — Jamaica — Haiti — Puerto Rico, being divided roughly into two parts by a narrow ridge of Cayman. The latter ridge is a continuation of the Sierra Maestra Mts. in Cuba, rising above sea level as the islands Gran Cayman. On the east, the ridge is suddenly truncated by an elevation of the plateau Misteriosa. North of it stretches the Yucatan Basin having maximum depth of 4,709 metres. On the south, between the ridge of Cayman and Cuba on the one hand, and the ridge Honduras—Jamaica—Haiti on the other, extends the deepest part of the Caribbean sea — the narrow basin of Cayman. Greatest depths have been measured at the northern steep dip of the

basin; here it takes the form of a graben. South of the Cayman Islands lies the Bartlett Trough having a depth of 6,950 metres and south of the Cuban mountains Sierra Maestra, the Oriente Graben 7,243 metres deep. It represents, together with the peaks of the Sierra Maestra Mountains (2,000 metres), one of the greatest height differences on the earth.

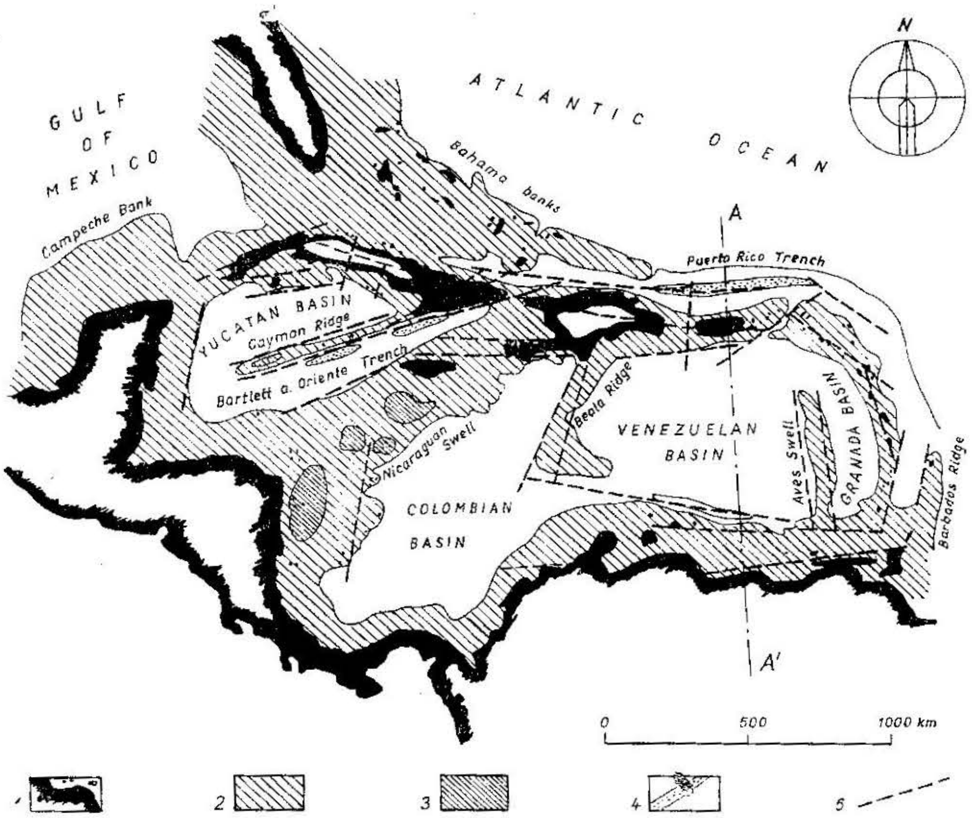


Fig. 2. Scheme of the submarine topography and of the main features of the fracture tectonics of Caribbean Region. *1* — islands and continents; *2* — shelf and submarine elevations; *3* — banks; *4* — submarine trenches; *5* — main faults

The highly dissected Caribbean region is not an incidental feature. It may be anticipated that the submarine elevations are continuation of the structures running from the continent and the island chain. It is very likely that this applies to the ridges of Cayman and Beata, as well as to the elevation Honduras—Jamaica—Haiti—Puerto Rico to which Palaeozoic structures of Honduras are directed. Remarkable are also the features of submarine topography in detail (B. C. Hecken — A. S. Laughton 1963). The slopes of the ridges are more or less straight (Cayman, Beata) and steep, the bottoms are relatively flat. This suggests that the ridges are set on faults (fig. 2). Such a hypothesis is also supported by the configuration of some of the islands in the Greater Antilles — almost rectangular outlines of Puerto Rico, peninsulas in the west

part of Haiti, north shore of Jamaica, south shore of the Sierra Maestra Mts. in Cuba (with faults evident on dry land).

Geophysical measurements (M. Edwing et al. 1955, 1957, M. Talwani et al. 1959) gave important data on thicknesses of sial. In the area of individual islands and submarine ridges, the earth's crust is 20—30 km thick but in depressions, 10—18 km thick and takes on a transitional character. Contrary to the continent, the sialic crustal layer is of smaller thickness; contrary to the oceanic type, it contains igneous rocks and sediments 6—8 km thick. It is apparent that morphological dissection of the whole Caribbean region is accompanied by not less important geological dissection.

Notes to the geological genesis of the Antillean region

The Antilles are one of the known island arcs attractive for geologists for many years on account of genesis. Analysis of the geological structure of Cuba and its surroundings has revealed some aspects which, in our view, are in close connection with their genesis and have not so far been referred to, as far as we know, in such a context.

From the discussions given above it follows that, like in Cuba, the whole Caribbean region is differentiated by faults into several blocks. Although big, all fault structures are not of the same value for the geological development of the Caribbean region. We are inclined to the view that of supreme relevancy are deep faults which essentially form the backbone of the islands and directly affect the principal geological structures. The presence of ultrabasic igneous rocks, largely accompanying the faults, indicates that these faults reach considerable depths.

One of the characteristics of island arcs is the belt of gravimetric minima, which usually accompanies these islands along the axis of deep-sea grabens. Many authors made attempts to explain this phenomenon in various ways. In the Antillean region, the known theory of tectogene was applied (H. H. Hess 1938). The authors presume, contrary to the above theory, that the distinctly linear course of the long, narrow zone of a gravimetric minimum and its irregularity can be explained by the existence of a series of deep faults along which lighter magmatic masses ascended or the magma may have been differentiated to lower density. It is also possible that these systems of deep faults are filled with serpentinite. In all islands of the Antilles magmatites of andesite composition and granitoids of quartz-diorite to granodiorite composition strikingly predominate over largely carbonate sediments. This indicates a direct connection of surficial zones with deep portions of the earth's crust through linear supply channels represented by deep faults (fig. 3).

The narrow linear course of the groups of islands, and much information regarding the geological development of the Antilles, can by no means be found in agreement with the most recent paper on the geology of Cuba written by G. Furrazola et al. (1964). According to them, Cuba is the product of the so-called Cuban geosyncline which was differentiated in times into partial geosynclinal and geanticlinal structures. It is still obscure what is the relation of the Caribbean region and the Antilles to the Cuban geosyncline. The commonly accepted opinion is that the geosynclines represent areas with a long-lasting subsidence in which sediments of great thicknesses were formed. After their accumulation geotectonic conditions reversed. The result of this was

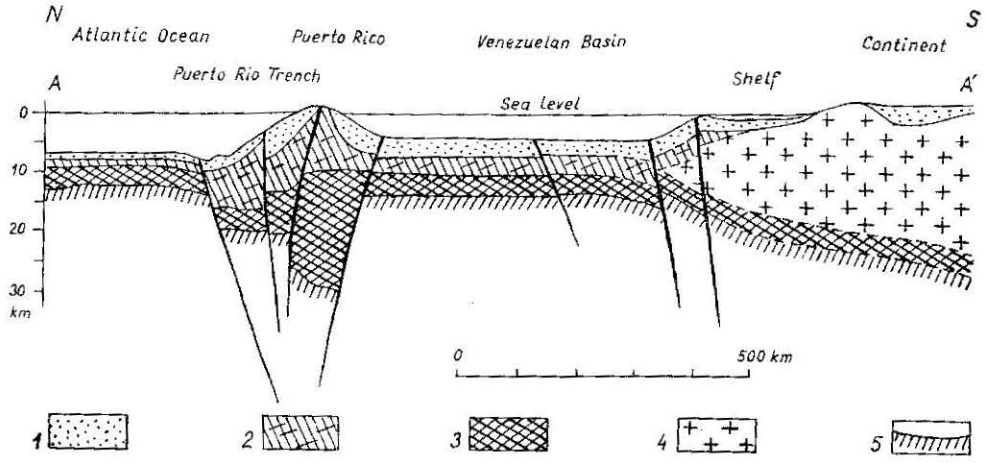


Fig. 3. Schematic view of the main geological relations in the Caribbean Region (section along the line A—A' in fig. 2) (elaborated partly according to geophysical data from M. Talwani et al. 1959, M. Ewing et al. 1955, 1957). *1* — sediments; *2* — crust of andesitic composition; *3* — basaltic crust; *4* — crystalline basement of continents; *5* — boundary between mantle and crust

orogeny, i. e. folding, metamorphism and ascent of granitoids. Such a development did not exist either in Cuba or other islands of the Greater Antilles, and not even in the Lesser Antilles. Much information on the geological development of the islands and the comparison with data obtained from geophysical measurements in the surrounding marine areas reveal that during its geological development the island arc formed a mountaineous ridge rising above the sea bottom, not a depression with a secular subsidence. At the same time we witness a very interesting phenomenon: although main features of the preceding geosynclinal development of the whole region are missing, both the Greater Antilles and part of the Lesser Antilles were subject to repeating folding processes, contain metamorphosed zones and numerous granitoid massifs. This suggests that these orogenic phenomena need not be only a direct consequence of the preceding geosynclinal development but primarily were produced by a high mobility of that region. As far as the Antilles are concerned, the mobility is function of a set of deep faults on which the islands are founded.

The authors recommend that the genesis of the Antilles be solved with respect to the following aspects:

1. In some islands there are series of large structural sutures which separate blocks with different geological development. These sutures can in a way be related to global structures in adjacent continents. Recent investigations have proved that the latter sutures continue even in the Pacific ocean (the faults Clarion, Clipperton, a. o.).

2. In the Antilles, an island arch is not developed in the proper meaning of the term. The belts of islands intersect in various directions. This fact may still better be understood in the analysis of the dissection of the bottom and geophysical picture of the Caribbean sea (fig. 2). Although there exist some significant features common for the islands, certain different features were also disclosed.

3. With regard to both morphological and genetical dependence of the islands on deep sutures, it cannot be expected that individual islands were either laterally shifted as blocks or torn off the adjacent continent, as presumed by some authors (J. J. Corral 1940).

4. It seems necessary that the genesis should also be solved with regard to a probable influence of the near continents.

On the basis of the author's remarks given above, it seems expedient to summarize briefly our opinion on the genesis of the islands as follows: the geological history of the Antilles can be divided into early and late development. There is still little information on the former. It can only be stated that in the area of the same mobile zone, a cycle of geological processes gave rise to a discontinuous ridge consisting of sialic rocks above oceanic bottom. Finally, accumulated sediments and volcanic rocks underwent a regional metamorphism. After these processes (believed to have taken place in Palaeozoic times) the lighter bloks first rose secularly above the oceanic bottom and then were eroded during long periods of time.

On this basement (palaeoantilides ? H. Stille 1942) a relatively quiet and slightly differentiated sedimentation of Upper Jurassic and Lower Cretaceous was followed, mostly at the end of the Lower Cretaceous, by processes leading to the rejuvenation of old suboceanic structural sutures or resulting in new sutures. This was an immediate consequence of the changes of force field in the earth's crust, brought about by shifts over large areas during the orogeny in extensive geosynclinal belts on the west of North and South America. Along the set of sutures a submarine volcanic ridge (largely of andesite composition) was gradually formed. But its growth, conditioned by the accumulation of volcanic rocks and a block uplift, did not take place uniformly. This unevenness was primarily the result of the intersection of structural sutures bounding single blocks, the activity of their uplift and the different distance from volcanic centres. Therefore, the ridge being produced was not a continuous one. The existence of the volcanic ridge basically conditioned a highly differentiated sedimentation which took place at the expense of the ejected volcanic material, as a result of its destruction and owing to the activity of rock-forming organisms. These are intensely favoured by the ridges coming close to the sea level. A steep dip of the slopes of the ridges and their seismicity were responsible for redeposition of limestone and clastic sediments in lower layers. In individual depressions deep-water sediments (radiolarian rocks) were laid down. The intensive mobility along structural sutures produced movements resulting in repeating fold and fault deformations. The most prominent folds may be expected especially at the margins of the blocks. Final products of magmatic processes in individual volcanic belts were the ascended granitoids largely of granodiorite and quartz-diorite composition. In some of permanently rising blocks an intense removal occurred, and so the metamorphosed zones cropped out.

The processes discussed did not take place evenly either in time or in space. The development of some belts caused a relative solidification of one part of a fault set, and the tectonic and volcanic activity produced new belts or rejuvenation and other weakened zones which need not run in parallel with the original zones. The whole process, i. e. another uplift and sedimentation, was repeated later in other place and more or less in a similar way. Such a phenomenon may well be studied by comparing central Cuba with the Sierra

Maestra Mountains; the uplift of the latter extended the island by a new volcanic belt more than 200 km long and 30 km wide. By analogy, the volcanic Lesser Antilles are believed by the authors to be the prototype of the relatively consolidated Greater Antilles.

The authors assume that the development of the island belts is one of the features that characterize the initial development of the geosyncline which has been forming probably since Cretaceous times between the two American continents. This developing geosynclinal area is named here the Caribbean geosyncline.

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RECENZE

Endogennye rudnye formacii Sibiri i Dal'nego Vostoka. — Izdat. Nauka, 221 str., Moskva 1966.

V květnu 1964 se konalo v Novosibirsku zasedání vědecké rady pro řešení otázek teorie vzniku a rozmístění rudních ložisek, která pracuje při Sibiřském oddělení Akad. nauk SSSR. Referáty z tohoto zasedání jsou obsahem sborníku.

Práce jsou věnovány problémům výzkumu rudních formací, jejich významu pro vypracování klasifikačního systému ložisek endogenních rud. Byly diskutovány základní pojmy, jako metalogenetická asociace, metalogenetický typ apod. Byly charakterizovány rudní formace různých metalogenetických oblastí a rudních rajónů. Problémy rudních formací byly posuzovány z různých hledisek. Z dvaceti tří referátů vyplývá různý přístup k chápání významu rudní formace, genetické řady formací, rudních komplexů. Většina autorů chápe rudní formaci jako skupinu ložisek látkově shodných svými minerálními asociacemi. Taková skupina se vyznačuje tím, že vzniká v podobných geologických podmínkách.

Vědecké rokování bylo ukončeno závěrem, v němž se konstatuje progresivita učení o rudních formacích a jejich praktickém významu pro studium metalogeneze a vytváření ložiskových prognóz. Naznačují se směry výzkumu, které by prohloubily formační rudní analýzu na základě sledování vztahů rudních formací s ostatními geologickými elementy, zvláště relace rud a magmatitů na základě srovnávání minerálních asociací endogenních rudních ložisek s magmatickými komplexy. Je zřejmé, že detailní studium rudních oblastí může vést k účelnému vymezení rudních formací jen při použití řady výzkumných metod. Závěrem se navrhuje, aby byla rozpracována obecná klasifikace rudních ložisek, která by brala ohled na geochemicko-fyzikální a formační principy. Terminologická nejednotnost vedla k návrhu

zřídit terminologickou komisi, která by se tímto problémem zabývala.

Snaha jednotlivých autorů po vymezení náplně pojmu rudní formace je vedena úsilím syntetizovat velké množství faktorů, které podmiňují vznik rudních ložisek. Autoři se snaží shrnout tyto řady faktorů, obsáhnout přirozené zákonitosti evoluce rudních mineralizací od počátku činnosti magmatických a rudních zdrojů až po působení geologického prostředí v jednotlivých etapách vývoje strukturních jednotek, v nichž ložiska vznikají a ukládají se.

V. A. Kuznecov obhajuje potřebnost zavedení pojmu formací rud, popisuje historii vývoje pojmu a ztotožňuje se se Zacharovem a R. M. Konstantinovem v tom, že rudní formace je skupina ložisek látkově shodných, se stálými asociacemi minerálů. Přitom zdůrazňuje, že jde o to, aby formace vyjadřovala i průmyslovost ložisek, tj. aby formace zahrnovala takové minerální asociace, které tvoří ekonomicky významné akumulace. Pak bude mít vymezení formací i prognózní význam. Požadavek zavedení pojmu formace zdůvodnil také tím, že nalézáme v přírodě přirozená rudní seskupení, která často musíme studovat bez ohledu na genezi.

R. M. Konstantinov chápe genetické řady magmatogenních formací rud jako série ložisek různých rudních formací, typických určitým vývojem minerálních asociací. Konstatuje možnosti existence několika současně existujících zdrojů rud uvnitř jednoho magmatického krbu.

E. A. Radkevič se zabývá klasifikací ložisek, uvádí vývoj klasifikačních kritérií od jednoduchého složení a morfologie ložisek přes klasifikace založené na zákonitém spojení vývoje asociace s vývojem daného úseku zemské kůry až ke klasifikaci založené na strukturně tektonickém principu pro oblasti, jež se vyvíjely polycyklicky. Poukazuje na to, že v různých typech geologických struktur se mohou opakovat shodné rudní formace. Rozvíjí představu o křemito-alkalické linii tvorby rud a linii Fe-Mg-sulfidické.

F. N. Šachov se zabývá principy systematiky ložisek vznikajících z horkých roztoků a dochází k závěru, že tato ložiska je nutno dělit na metasomatická se stálými minerálními komplexy a žilná ložiska s komplikovaným minerálním složením. Proto doporučuje rudní formace na žilných ložiskách charakterizovat pomocí prvků, a ne minerálů.

V. N. Kotljar popisuje vztahy magmatických komplexů a hloubky vzniku rudních ložisek. G. V. Icikson a V. T. Matveenko studují metalogenní asociace ve vulkanických zónách tichooceánského rudního pásu. Navrhují zavést pojem metalogenní asociace. Je to přirozené seskupení historicky závislých geologických fenoménů, vznikajících v konkrétním prostoru, s nímž je zákonitě spjat vznik určitých minerálně geochemických typů ložisek, jejich skupin nebo asociací (metalogenních asociací). Metalogenní asociace je tedy seskupení geologických formací magmatických, metamorfních, sedimentárních a rudních.

V. V. Bogackij uvádí zásady rajónování geosynklinál a klasifikace endogenních ložisek. Další část sborníku je věnována konkrétním rudním formacím v různých oblastech, problematice ložisek zlata, mědi a niklu, ložiskům sulfidicko-kasiteritovým, wolframovým, olověno-zinkovým a rtuťovým. Do této části je též zařazen referát P. F. Ivankina o zonálním rozmístění rudních formací. Ze studia W-Mo-pásu hornoaltajské oblasti, polymetalického pásu Rudního a Jižního Altaje, zlatorudného pásu Jižního Altaje a kalbanarymského pásu se vzácnými kovy vyplynuly požadavky na zpřesnění pojmu rudní formace, rudní komplex, genetický typ rudní mineralizace. Rudní formace se vysvětluje jako společenstvo asociací rudních a nerudních minerálů, tvořících se v určitých geologických podmínkách. Rudní formace je částí magmatického komplexu. Magmatická řada je společenství magmatitů spojených s činností jediného hlubinného krbu, který je v činnosti během jednoho tektonického cyklu. Magmatické řadě odpovídá chalkofilní metalogenní řada, což představuje společenstvo rudních komplexů, spojených mezi sebou teritoriálně a komagmatickými vztahy rudogenetických komplexů hornin příslušné magmatické řady. Autor definuje rudní komplex jako společenstvo (nakupení) endogenních ložisek různých genetických typů, spjatých svým původem s určitým magmatickým komplexem, jeho vývojovými fázemi a intruzemi. Genetický typ mineralizace je skupina formací daného komplexu, vázaného na společný magmatický zdroj a také podobné termodynamické a fyzikálně chemické podmínky vzniku. Z práce vyplývá, že klasifikace endogenních ložisek a rudních projevů podle formačních a genetických principů má místní (provinciální) význam. Celý sborník ukazuje živost diskutované problematiky a snahu rozpracovat náplň pojmu rudní formace. Cílem studií je vypracování vědeckých principů prognóz endogenních rudních ložisek pod syntetizujícím zorným úhlem, zahrnujícím širokou škálu faktorů podmiňujících konkrétní lokalizaci průmyslově významných ložisek.

Petr Orel