ISRAEL GEOLOGICAL SOCIETY

PROCEEDINGS OF SYMPOSIUM ON EPIGENETIC PROCESSES IN CARBONATE ROCKS

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PROCEEDINGS OF THE ISRAEL GEOLOGICAL SOCIETY

The influence of physical properties on the weathering processes of calcareous rocks

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Physical weathering of rocks results in the fragmentation of a compact block into small particles, enhancing thereby chemical leaching. In the mountainous regions of Israel, fissures and cracks are found in hard calcareous rocks which were formed by physical weathering and then broadened by the action of water containing carbon dioxide or other acids.

Physical weathering is due to a number of factors. While the weathering process depends on external factors which are not connected with the rock itself, the rate of their activity is directly linked to the rock's internal structure and is evident in the physical properties of the rock.

Two main types of calcareous rocks are found in Israel, each posessing different physical properties.

1. *Hard rocks,* e.g. lithographic limestone, dolomite, marble, meleke (macro-crystalline limestone), *etc.*

2. *Soft and medium hard rocks, e.g.* chalk, marly chalk, marl, kurkar (calcareous sandstone), *etc.*

Determinations of porosity, mechanical properties, water movement by infiltration, capillary rise, evaporation and thermal properties of the different calcareous rocks indicate that outstanding differences exist between the properties of the soft and hard calcareous rocks. The influence of these properties on weathering activity is considerable, and the differences in the weathering products of the soft and hard calcareous rocks can be explained from the above conclusions. While the weathering residue from hard rocks is poor in lime, the residue from soft rocks is rich in lime, containing between 30% to 70% of calcium carbonate.

The calcareous rocks of Israel, which cover large areas in the mountainous region, are important raw materials in the chemical industry, building and agriculture. It is advisable to promote the study of their properties in the same way as other industrial minerals are studied in this country.

Dynamics of limestone solution and its application in the interpretation of geological processes

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By dynamics of limestone solution we understand the totality of reactions and movements that are continuously taking place in the $CaCO_3$ system under the influence of the environmental forces acting upon it.

The solubility relationships of $CaCO_3$ in limestone or in other calcareous rocks in nature are not different from that of pure calcium carbonate when studied in the laboratory. From these studies it is known that the major factors affecting the solubility of $CaCO_3$ are CO_2 pressure, *p*H and ionic strength (concentration of soluble salts and common ions) of the solvent solution, while the rate of solvent exchange is of greatest importance in controlling the rate of solution. For each temperature there exists an overall equilibrium condition, which is governed by at least five participating partial equilibria. Quantitative data of limestone solubility under various environmental conditions can be obtained by considering the interaction of these separate equilibrium states.

Evidence of limestone solution in nature by waters constantly or periodically undersaturated with calcium carbonate are the caverns, sinkholes and other irregularities of a karst landscape, the development of underground limestone aquifers, overhanging sea-level nips, and shallow tidal solution basins in coastal limestones. Solution of limestone and metasomatic volume by volume replacement at low temperature and pressure by mineralized ground-waters is responsible for the formation of epigenetic dolomites, which are locally important as oil or water reservoirs. A special case of partial limestone solution and recrystallization under semiarid conditions is Naritization, forming a crust-like layer capping porous limestones and marls. Solution and local reprecipitation of calcium carbonate causes the consolidation of calcareous dunes into the Kurkar beach rock. Differential solution and leaching of calcium carbonate, accompanied by certain alteration processes of the silicate minerals, takes place during surface weathering of limestones and the subsequent development of calcareous soils, such as Rendzina and Terra rossa. Though complex, the nature of these different natural processes can be elucidated from the considerations of the principles of limestone solution and its behaviour under the influence of all the interrelated factors.

The rate of weathering and denudation of a limestone area depends upon the volume of precipitation and upon its capacity to dissolve limestone. From data of average rainfall and runoff conditions of the Mediterranean climate and the average calcium content of ground water we estimate the rate of denudation by solvent action to be about 10 microns annually. For humid temperate climates the rate is 2 to 4x higher.

The total average erosion in the central parts of Israel since the emergence of the land some 35 million years ago, and assuming from stratigraphic analysis that a layer of about 300 to 350 m of mostly calcareous Eocene, Senonian and Turonian rocks have been removed by erosion, is of a similar magnitude, or about 10 mm per 1000 years.

The development of nari*

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In the mediterranean region of Palestine many permeable calcareous rocks develop a weathered surface crust known as *nari*, which is sometimes capped by a hard compact secondary crust.

Observations in thin sections and measurements of density and percolation indicate that compared to the underlying bedrock the nari is more porous, its crystals are larger and more interwoven. The hard secondary crust is non-porous and its particles largely recrystallized and cemented .The thickness of the nari crust is directly related to the permeability of the underlying base rock.

Results from chemical analyses show that when going from the base rock upwards, the clay content, *i.e.* the insoluble residue, first decreases and then again increases in the secondary compact crust; the percentage of carbonates increases in the nari but again decreases in the compact crust. The nari, while having a characteristic structure, lacks a typical chemical composition.

The research proves that nari develops by alteration within the rock itself, by terrestrial weathering under conditions of a mediterranean climate. During the winter there prevails dissolution by percolating rain water, in summer there is precipitation from water raising through capillary forces. Cool winter water dissolves the carbonates in the larger pores, while from the warm summer water clay is flocculated at the surface and the carbonates just below. The precipitation takes place in the small pores, while solution continues to act in the large pores. As a result of the cyclic solution–precipitation processes the surface is enriched in clay, its pores are being filled and the particles cemented resulting in the compact crust being formed. Below it the rock becomes enriched on carbonates, its porosity increases and its crystals become enlarged and interwoven — the nari has been formed.

The same weathering cycle, when acting on non-permeable rocks or when leaching prevails, gives rise to the formation of terra rossa soil and in fissured rocks to karstic phenomena. Thus the distribution of nari and terra rossa or karst are mutually restrictive.

Porosity characteristics of carbonate rocks in Israel

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Total porosity of sedimentary rocks reaches 30% to 40% of their volume. A considerable part of this porosity is composed of capillary pores, which do not enable free movement of ground water. From the hydrologic point only pores with an average diameter larger than 0.1 mm are significant and comprise the "effective porosity".

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* Based on the author's Ph.D. thesis at The Hebrew University of Jerusalem, 1958.

Values of effective porosity vary from 1% in Turonian limestone of the southern Carmel, 3% to 5% in the dolomitic Turonian-Cenomanian aquifer of Western Galilee, and up to 12% in the Turonian-Cenomanian aquifer of the Lod foothills, However, the pore volume does not evaluate sufficiently all the porosity characteristics. and it is also necessary to know the pattern of the pores and the pore size distribution. An effective method to test the porosity characteristics is the pumping test. From these and other tests the following results were obtained so far.

Dependence of porosity on lithology. Generally only hard rocks exhibit a high effective porosity. This is due to fractures and fissures, and their enlargement by dissolution. Among the hard rocks limestones usually show clear signs of karstic features (*e.g.* the Turonian borings at Lod, and Ramon 1 in Western Galilee). Dolomitic rocks often develop a homogeneous porosity as a result of selective dissolution, which eventually alters the rocks into "dolomitic sand", as found in a number of borings at Kfar Uriya and Beersheva. An example of increased porosity through dissolution of hard rock is found in the Turonian-Upper Cenomanian aquifer in the region Wadi Keziv — Kabri in the Western Galilee.

Decreased porosity with depth. Theoretically it would be expected that because of pressure porosity will decrease with depth. However, this assumption is not confirmed from borings in carbonate rocks. Highly porous rocks are found at the depth of 800 m (Taanach boring), and oil well borings (at Zikhron Yaaqov, Motza and Tiberias) encountered very porous dolomite and even caverns at depths of 1000 m and more.

Development of solution channels along bedding planes. It is well known that borings in tilted beds usually have to be drilled to a greater depth before achieving the expected yields of water (borings of Kfar Uriya compared to borings of Hartuv). Such evidence supports the assumption that groundwater flows largely in solution channels along bedding planes.

Porosity in relation to tectonics, especially faulting. In theory the intensive fracturing in fault zones should increase the effective porosity and result in good hydraulic conduction. Practical experience does not entirely confirm this assumption. High hydraulic conductivity was found in borings near faults (Acre, Yagur, Shimron), but also distant from faults (Wadi Ara 2, Wadi Falah, Damon 1, Lod 20, *etc.*). Several borings in faulted zones gave disappointing results or showed only an average conduction (Shlomi, Tel-Adashim). On the other hand experience shows that regional karstic features and the development of high porosity is influenced mainly by the older fold structures, especially anticlinal promontories.

Diagenetic processes in carbonate rocks as inferred from the geochemistry of groundwater in Israel

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The observations reported here are based on the evaluation of numerous groundwater analyses obtained from Tahal and on published data from Israel and from abroad.

The waters of the karstic aquifer of northern Israel contain a relatively high amount of HCO_3, while the SO_4/Cl ratio is similar to that of sea water. When the calculated contribution of sea water salts is subtracted, it is found that in the terrestrially derived solutes the ratio Mg/Ca increases with increasing salinity. When the ratio through the influence of sea water exceeds one, at a total salinity of about 500 to 600 ppm, magnesium is exchanged for calcium from the solid phase, resulting in *dolomitization*. In more concentrated solutions Mg is increasingly exchanged for Ca in the solid phase and very saline waters of marine origin reach a Ca/Mg ratio of about 2. The process of dolomitization has presumably taken place during the emergence of the sediments from the sea.

The above process is retarded or even reversed by the presence of sedimentary or residual gypsum. The high concentration of dissolved Ca from $CaSO_4$ may lead to the exchange of Ca for Mg from dolomite, causing *dedolomitization*. This is evidenced by the high concentration of magnesium in sulphate-rich waters.

On the occurrence of dolomitization in sedimentary rocks of Israel

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Solution basins in Kurkar near Natanya

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Some remarks on solution processes along the cliff coast of Israel

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