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PROBLEMS OF THE GENESIS AND GENETIC CLASSIFICATION OF MAGNESITE DEPOSITS

(Figs. 1—5)

Abstract: Since 1950 magnesite deposits of the Balkan Peninsula (in the zones of ultrabasic rocks of the Dinarides and Helenides) have been subject of detailed study as a raw material basis for the industry of high refractory materials. This research yielded a number of new and very important data for a general knowledge of the genesis of magnesite and enabled us to put forward a new, more complete classification of magnesite deposits.

Introduction

Although magnesite, one of the basic raw materials for the production of high-refractory materials, has been exploited for a long time, many problems of its genesis have not so far been definitively solved. Theories of the most eminent research workers engaged in the study of this problem differ considerably in the following important points:

1. Which processes occurring in nature bring about the formation of magnesite;
2. What sources has the magnesium found in various types of magnesite deposits been derived from;
3. Under what physico-chemical conditions have various types of magnesite deposits been formed.

Special difficulties are encountered in the fact that magnesite deposits in different parts of the world are represented by different types of deposits. As a result the problem of the genesis of magnesite was usually treated one-sidedly by taking into account relatively small areas and some types of deposits. Only a small number of scientists have dealt complexly with this problem taking into consideration all the possible processes leading to its formation. The best known genetic classifications of magnesite deposits are those of G. Bain (1924), P. M. Tatarinov (1946), J. P. Destombes (1956), and W. E. Petrascheck (1961).

Due to frequent occurrence and diversity of magnesite deposits the zones of Paleozoic ultrabasic rocks of the Dinarides and Helenides, the so-called Balkan magnesite area, in one of the most important in Europe. Of the types of magnesite deposits so far known in the world the vein and infiltration types are found here, while metasomatic and saliferous types have not yet been observed. On the other hand, in the Balkan magnesite area there are also some specific types of magnesite deposits such as hydrothermal-sedimentary and detrital types that have not been observed in other parts of the world.

The following will be a short survey of the distribution and economic importance of various types of magnesite deposits on the Balkan Peninsula.

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The vein type of deposits accompany the ultrabasic massifs of the Dinarides and Helenides. Since in many localities deposits of this type are represented by systems of thick veins containing good quality ore they are the main magnesite deposits of this area.

The infiltration type is only represented by small, practically uninteresting magnesite occurrences.

The hydrothermal-sedimentary type often occurs in fresh-water Miocene basins in the area of the Balkan ultrabasic massifs. It is sometimes represented by large magnesite ore bodies of great economic importance.

The detrital type is also found in young Tertiary or Quarternary basins in the area of ultramafic massifs. It is generally represented by small, economically uninteresting occurrences of magnesite-bearing conglomerates.

By taking into account all so far known genetic types of magnesite deposits, both occurring on the Balkan Peninsula and in other parts of the world, it is possible to set up a new, at present the most complete classification. This new, appreciably expanded classification of magnesite deposits is given in the table below (tab. 1).

As is evident from the table, magnesite is formed both in the endogenic cycle (hydrothermal deposits) and in the exogenic cycle (sedimentary deposits s. str. and deposits resulting from weathering). In addition, there are transitional hydrothermal-sedimentary deposits.

It is important to point out that in the genesis of hydrothermal and hydrothermal-sedimentary deposits, magnesium is not introduced directly from magma chambers. It is well known from geochemistry that in the process of solidification of magmatic melts this element nearly completely links itself with mafic minerals of the main phase of magmatic crystallization, so that it is not characteristic for the hydrothermal stage. However, significant concentrations of magnesium carbonate in hydrothermal (and hydrothermal-sedimentary) field could be formed by lateral secretion (secondary hydrothermally), i. e. in passing through the rocks rich with magnesium (peridotites, serpentines, dolomites) hydrothermal solutions containing carbonic acid tend to leach magnesium from them, to transport it

Table 1. A genetic classification of magnesite deposits

I. ENDOGENIC (HYDROTHERMAL) DEPOSITS
1. Metasomatic type
2. Vein type
II. TRANSITIONAL HYDROTHERMAL-SEDIMENTARY DEPOSITS
1. Bela Stena type
III. EXOGENIC DEPOSITS
A. Sedimentary deposits s. str.
1. Saliferous type
2. Detrital type
B. Deposits resulting from weathering
1. Infiltration type

in the form of magnesium bicarbonate and to deposit it in the form of magnesite in convenient places.

The following will be a discussion of basic characteristics of all six genetic types of magnesite deposits.

I. ENDOGENIC (HYDROTHERMAL) DEPOSITS

1. Metasomatic Type

The hydrothermal-metasomatic type of magnesite deposits is represented by extensive magnesite bodies (beds, lenses, stocks) lying in limestones and dolomites. To this type belong the largest and economically most important deposits in the world: Manchurian (Tahsichiao-Haicheng area), Korean (Gozui, Tanzengun), those of the Soviet Union (Satkinskne, Savinskoe), Austrian [Radenthein, Veitsch (fig. 1) and Trieben], Czechoslovakian (Dúbrava, Košice), Spanish (on the West Pyrenees), North-American (Stevens and Gabbs, USA, Grenville, Canada), etc. Deposits of this type usually have considerably large reserves — from a few million to several tens of million tons, sometimes several hundred million and even several thousand million tons. Magnesite deposits of the metasomatic type have not so far been discovered on the Balkan Peninsula.

In metasomatic deposits magnesite occurs in granular, usually very coarse-grained aggregates so that these are often called deposits of crystalline or spathic magnesite. Magnesite grains range from a few parts of millimeter to several centimeters in size. Their color is usually white or yellowish, but can also be gray to completely black. The main undesirable impurities are calcia and iron. Intercalations of dolomite that remained unaltered during metasomatic replacement are often encountered in this magnesite.

The genesis of crystalline magnesite deposits is still controversial and there are two opposing theories. The larger group of scientists (G. Bain 1924, W. Petrascheck 1931, A. Himmelbauer 1933, K. A. Redlich 1934, P. M. Tatarinov 1946, etc.) hold that these deposits have been formed by metasomatic replacement of limestones and dolomites by hot magnesium-charged hydrothermal solutions, while the other group (H. Nishihara 1956, C. Martin 1956, G. J. de Llarena 1959) believe that these deposits were formed by sedimentation.

Proponents of the theory of the sedimentary origin of spathic magnesite assume that magnesite deposits of this type were formed by precipitation in sea

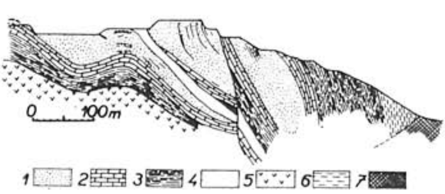

Fig. 1. Cross section through the metasomatic magnesite deposit Sattler Kogels near Veitsch, Austria. (After W. Petrascheck.) Legend: 1 — Magnesite, 2 — dolomite, 3 — Carboniferous schist, 4 — porphyroid, 5 — keratophyre, 6 — graphite-schist, 7 — gneiss.

lagoons under specific (arid) climatic conditions. This theory has been best elaborated by H. Nishihara (1956).

Adherents of the theory of metasomatic origin of spathic magnesite base their concept on the following:

1. On the mineral paragenesis. Crystalline magnesite generally contains dolomite, calcite, aragonite, siderite, talcum, chlorite, quartz, barite, pyrite, chalcopyrite, galenite, sphalerite, goethite, tetrahedrite, and carbonaceous matter. Most of these are typical hydrothermal minerals.

2. Textural characteristics. Spathic magnesite often has a pronounced metasomatic textures such as banded, radially fibrous, stellar, or pinolitic.

3. Changes in fossil material. It was observed in Austrian deposits that crinoid stems embedded in ore bodies had been altered into dolomite and magnesite while the same fossils occurring outside the deposits consists of calcium carbonate.

4. Magnesium content increases gradually from the surrounding carbonatic rocks towards magnesite ore bodies.

5. Interrelation between magnesite and siderite deposits. In Austria (Veitsch-Erzberg) and in the USSR (Satka-Bakal) there is a close relation between deposits of spathic magnesite and hydrothermal siderite deposits.

6. Evidence obtained by experimental study of carbonatic systems. B. N. Ryzhenko (1963) has established that in contact with dolomites or magnesium silicites hydrothermal solutions containing carbonic acid can leach magnesium and combine it into a bicarbonate. In the form a bicabonate solution magnesium can be transported for considerable distances.

As to the problem of the source of hydrothermal solutions required for metasomatic replacement of limestones and dolomites the most complete explanation is that offered by P. M. Tatarinov (1946). According to him, hydrothermal solutions can be derived from intrusions of acid or basic magmas.

In their ascending movement hydrothermal solutions (probably containing carbonic acid) leached megnesium from dolomitic series or masses of ultrabasic rocks (peridotites, serpentines) lying at greater depths and deposited it in limestone-dolomitic series lying at smaller depths whereby limestone and dolomite were metasomatically replaced.

In our opinion more direct and considerably more convincing evidence is available to the proponents of the theory of hydrothermal-metasomatic origin of spathic magnesite. Although real primary-sedimentary magnesite deposits are also found in nature, present evidence does not allow us to explain the origin of spathic magnesite in this way. As mentioned in this section on the saliferous type of magnesite deposits, they form under very specific climatic and other conditions, which is not the case with deposits of spathic magnesite.

Therefore, according to the present knowledge of these problems, deposits of spathic magnesite belong to mesothermal metasomatic deposits formed by means of hot ascending solutions at moderate depths. In the formation of these deposits magnesium is not introduced from igneous chambers; it is leached from deeper lying rocks (dolomites or ultrabasic rocks) by hydrothermal solutions (lateral secretion).

2. Vein Type

The hydrothermal-vein type of magnesite deposits occurs mainly in the form of veins or veinlets (stockworks) in ultrabasic rock masses (peridotites and serpentines). If the world production is considered, these deposits furnish only a comparatively small portion of magnesite, whereas on the Balkan Peninsula they are the commonest and most important sources of this raw material.

The largest and economically most interesting Balkan deposits of vein magnesite are those occurring on Yugoslav territory. These are Goleš (fig. 2), Dubovac, Brezak, Trnava, Liska, Banja Luka, and Kladanj. The following Greek deposits are also of economic interest: Vavdos, Euboea, Mitilene. Besides these, important deposits of vein magnesite are those in the USSR (on the Urals, southern Siberia), Austria (Kraubath), Polland (Lower Silesia), India (Madras), South Africa (Transvaal), USA (California), etc. Reserves of vein magnesite in individual deposits range from several hundred thousand to several million tons.

Magnesite occuring in vein deposits is cryptocrystalline, less often microcrystalline. It is very dense and of a conchoidal fracture, usually snowy white in color, though owing to the presence of various impurities it can be variously

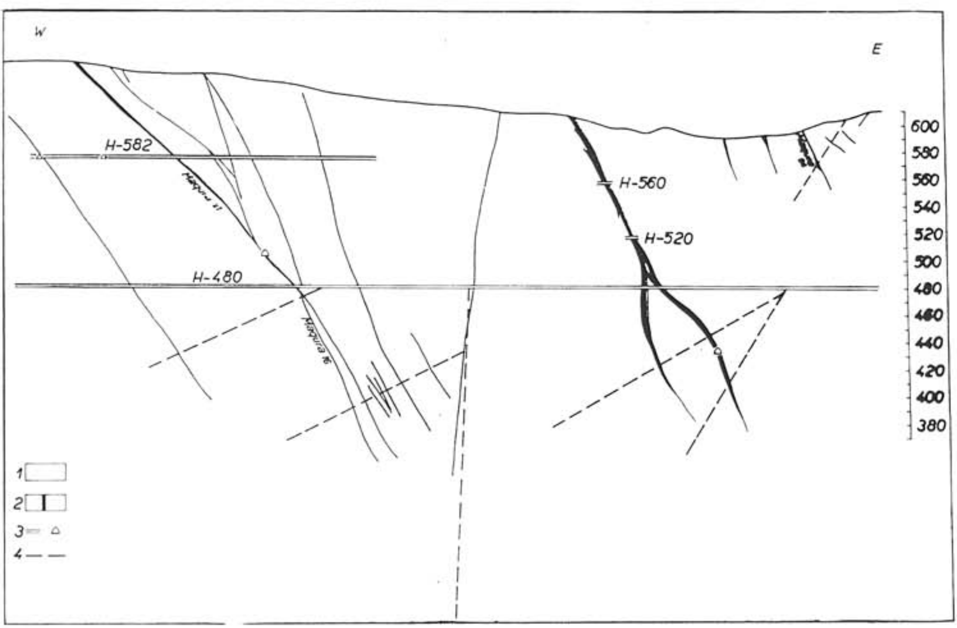

Fig. 2. Cross section through the vein magnesite deposit Goleš, Yugoslavia. Legend: 1 — Serpentinized peridotite, 2 — magnesite veins, 3 — mining works, 4 — borings.

colored (creamy, yellowish, gray). Its main undesirable ingredients are silica and calcia when present in high concentrations.

Deposits of vein magnesite used to be taken for infiltration formations resulting from weathering of ultrabasic rocks. This interpretation can occasionally be found even today although in view of evidence obtained by field and laboratory study of a large number of deposits of vein magnesite it has been established that these are distinctly hydrothermal formations.

Proponents of the hydrothermal origin of vein magnesite (P. M. Tatarinov 1946, M. Donath 1955, 1957, W. E. Petrascheck 1961, Miloje Ilić 1964, 1965) base their conclusions on the following:

1. Great length, thickness, and especially considerable vertical extent of magnesite veins. For example, in the Goleš mine, Yugoslavia, some veins have a length of 1200 m, maximum thickness up to 20 m, and a vertical extent of over 300 m.

2. Vein magnesite deposits are allways closely associated with fault zones and volcanic activity (especially thermal springs).

3. Vein magnesite deposits fit in well into definite tectono-magmatic cycles and corresponding mineralization epochs. Thus, e. g. all over the Balkan Peninsula these deposits were formed in the late stage of the Alpine cycle (in the Miocene) and were associated with subsequent volcanism.

4. Results of laboratory examination of magnesite. Numerous microscopic, X-ray, differential-thermal and spectrochemical examinations, and isotope analyses of Yugoslav vein magnesite have shown that vein magnesite deposits are typical hydrothermal formations.

5. Evidence provided by experimental study of carbonatic systems (especially that of B. N. Ryzhenko 1963).

Our approach to the problem of the genesis of vein magnesite was published in 1964 and 1965. Study of extensive documentation on vein magnesite of the Balkan Peninsula has led us to certain general conclusions on the genesis of this type of deposits.

It is an irrefuatable fact that vein magnesites occur exclusively in peridotite-serpentine massifs.

Removal of magnesium ion from ultrabasic rocks and its transport to the point of deposition is accomplished by means of hydrothermal solutions containing carbonic acid. In their ascending movement through fault zones they attack mineral components of ultrabasic rocks (olivine, pyroxene, serpentine) leach their magnesium and transport it in the form of bicarbonate. The complex HCO_3^- anion plays the main role in these processes. In the cases when solutions containing carbonic acid act on mineral components of fresh peridotites (primarily olivine) these are first altered into serpentine with liberation of excess magnesium (reaction 1). New amounts of solutions containing carbonic acid destroy serpentine, too, liberating magnesium and leaving silica behind (reaction 2).

$$2Mg_2SiO_4 + 2H_2CO_3 + H_2O = H_4Mg_3Si_2O_9 + Mg(HCO_3)_2 \quad (1)$$
$$H_4Mg_3Si_2O_9 + 6H_2CO_3 = 3Mg(HCO_3)_2 + 2SiO_2 + 5H_2O \quad (2)$$
$$Mg(HCO_3)_2 = MgCO_3 + CO_2 + H_2O \quad (3)$$

After it has been carried for a certain distance bicarbonate decomposes and magnesium carbonate precipitates (reaction 3). This is due to the escape of CO_2 in open fissures or owing to a change in the chemistry of hydrothermal solutions as a result of their mixing with descending solutions. Leaching of magnesium takes place in the deeper, its precipitation in the shallower parts of ultrabasic massifs. Examination of vein magnesite from many Yugoslav localities has shown that it precipitates at pH = 7,5—9,5 and at Eh = −70 to −120 mV.

This shows that vein magnesite deposits are meso- to epithermal formations laid down at small depths. Like in metasomatic deposits, magnesium contained in vein deposits does not originate from the magma chamber. This magnesium is leached by hydrothermal solutions (lateral secretion) from deeper lying ultrabasic rocks (peridotites and serpentinites).

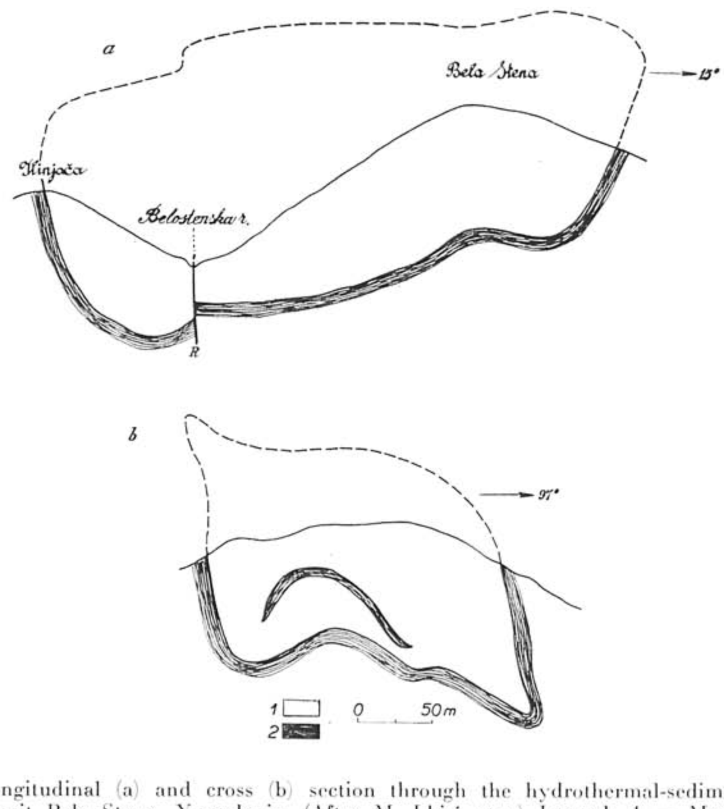

Fig. 3. Longitudinal (a) and cross (b) section through the hydrothermal-sedimentary magnesite deposit Bela Stena, Yugoslavia. (After M. Ilić, sen.) Legend: 1 — Magnesite, 2 — Miocene sediments (shales and marls).

II. TRANSITIONAL HYDROTHERMAL-SEDIMENTARY DEPOSITS (BELA-STENA TYPE)

The hydrothermal-sedimentary or the Bela-Stena type of magnesite deposits occurs in the form of lenses and beds in sedimentary series of fresh-water basins of Miocene age. The prototype of these deposits is that found in the locality Bela Stena (fig. 3), the Jarando Miocene basin, near Raška, Yugoslavia. It was first investigated and described by M. Ilić, sen. (1952).

The Bela Stena magnesite deposit is the first of its kind reported in the geological literature. After its discovery other nine occurrences of this kind of magnesite were found in Yugoslavia (Beli Kamen, Šilopaj, Lunjevica, Rvati, etc.), one in Greece (Aiani) and one in Turkey (Bozkurt).

A characteristic feature of hydrothermal-sedimentary magnesite deposits is that they usually have the form of large magnesite bodies occurring singly or in groups and containing considerable reserves of valuable substance (from several hundred thousand to several million tons). For instance, the Bela Stena deposit has a total reserves of over five million tons and is the largest magnesite deposit in Yugoslavia. In contrast to vein magnesite deposits which are generally mined underground, deposits of hydrothermal-sedimentary magnesite can mostly be mined open-pit.

Magnesite found in hydrothermal-sedimentary deposits is microcrystalline to cryptocrystalline, dense, and often of conchoidal fracture. Its color is usually gray (due to the presence of organic matter) but can also be white. Magnesite of hydrothermal-sedimentary deposits is of appreciably lower grade than that of vein deposits. This magnesite is often intercalated with marls and shales, and its main undesirable ingredients are high contents of calcia, silica, and sometimes alumina.

According to M. Ilić, sen. (1952), the Bela Stena deposit was formed in the following way. Magnesium from fractured ultrabasic rock masses underlying the lake was leached by means of ascending hydrothermal solutions of the Miocene volcanism and transported in the form of bicarbonate. On the discharge of solutions into the former Jarando lake the bicarbonate decomposed owing to a sudden escape of CO_2 with the resulting precipitation of magnesium carbonate. Since the formation of this deposit was associated with both hydrothermal and sedimentary processes the above author termed this kind of magnesite deposit the hydrothermal-sedimentary type.

The hydrothermal-sedimentary origin of deposits of this type is substantiated by the following:

1. It is not possible for magnesite to occur as an ordinary sediment in fresh-water basins. As has been explained in detail in the section on saliferous magnesite deposits, fresh water is a medium in which concentration and precipitation of magnesium salts is impossible without influence of certain external factors.

2. Oberservation that deposits of this magnesite are always associated with fault zones and volcanic activity (especially thermal springs).

3. The established fact that magnesite bodies of this type of deposits have very changeable lateral extent and occur at different levels in the stratigraphic column of the productive basins. This shows that they were not formed under ordinary sedimentation conditions; they are of strictly local occurrence and are fault zones and volcanic activity (especially thermal springs).
former lakes.

4. Like the vein type, deposits of hydrothermal-sedimentary magnesite were formed in a single mineralization epoch and therefore occur in sedimentary series of a given age (Miocene).

5. Presence of ultrabasic rocks around and below productive basins.

6. Results of laboratory study of hydrothermal-sedimentary magnesite by microscopic, X-ray, differential-thermal, spectrochemical and sedimentological methods, as well as isotope analyses. These examinations have shown that in its mineral and chemical composition, physical properties, and formation conditions (pH und Eh) hydrothermal-sedimentary magnesite is very similar to vein magnesite.

7. Results of experimental study of carbonatic systems (particularly those of B. N. Ryzhenko 1963).

All this shows that the genesis of hydrothermal-sedimentary magnesite deposits has many elements in common with the genesis of vein magnesite deposits. On the Balkan Peninsula both these types of magnesite deposits have been formed in the same mineralization epoch — in the Miocene.[1] The same hydrothermal solutions, containing carbonic acid, of subsequent volcanism took part in their formation, while magnesium was introduced by lateral secretion of ultrabasic rocks (peridotites and serpentines). However, different places and media of deposition in which the magnesite substance has been precipitated are responsible for the fact that these magnesite deposits occur as different genetic types.

III. EXOGENIC DEPOSITS

A. Sedimentary Deposits s. str.

1. Saliferous Type

The saliferous type of magnesite deposits is rather rare and is formed under very specific conditions. Because of this many authors dealing with the problem of the genesis of magnesite did not include these deposits into their classifications. Only a rather small number of geologists (G. Bain 1924, J. P. Destombes 1956, A. V. Kazakov et all. 1957, W. E. Petrascheck 1961) have reported on this type of deposits.

On the basis of experimental study A. V. Kazakov et. all. (1957) have established that the precipitation of sedimentary megnesite is conditioned by the following:

[1] The most important Balkan deposits of some non-ferrous metals (Pb, Zn, Sb) and non-metals (asbestos) were also formed in this mineralization epoch.

1. A relatively high concentration of magnesium bicarbonate, i. e. a high alkaline reserve. According to test results of these authors the lower limiting value of the alkaline reserve at 60 °C is A = 6—8 milliequivalents/liter, while at lower temperatures this limiting value is higher.

2. A comparatively high content of carbon dioxide in the water content ($CO_2 \geqq 380$ mg/l; $\frac{CO}{A} \geqq 2{,}2$).

3. A low calcium content in the water — dry residue containig less than 50 mg CaO per liter.

Since in recent accumulation basins (seas, lakes) these conditions are not satisfied, magnesite does not form as a chemogenic sediment.

Special conditions such as arid climate, separation of entire basins or at least some of their parts, certain hydrochemical characteristics of a given basin (e. g. sodium or carbo-magnesium types of water), high content of CO_2 and high salinity are required for the formation of deposits of this type.

Since all these conditions have rarely prevailed, occurrences of saliferous magnesite are rather infrequent. Magnesite formed in this way is found in the rock salt deposits of Hall (Tyrol), Saint Pandelone (France), Golf and Yorkshire (England).

2. Detrital Type

The detrital type of magnesite deposits has been discovered only recently and so far only on the Balkan Peninsula. It was recognized and described by the present author (1964, 1966). We are actually concerned here with mechanical disintegration of existing magnesite deposits (vein or hydrothermal-sedimentary) and deposition of magnesite detritus in close-lying accumulation basins.

On the Balkan Peninsula we have so far observed three occurrences of detrital magnesite: two in Yugoslavia (Janok near Mataruška Banja spa, and Badanj on Kopaonik), and one in Greece [the island of Euboea (fig. 4)].

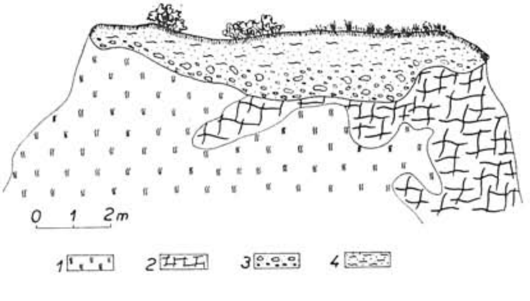

Fig. 4. Sketch showing the magnesite conglomerate at the locality Moraitis (Euboea, Greece). Legend: 1 — Serpentine, 2 — magnesite stockwork 3 — mostly magnesite conglomerates, 4 — clays and sands.

B. Deposits Resulting From Weathering

1. Infiltration Type

The infiltration type of magnesite deposits occurs in the crusts of weathering of ultrabasic rocks (peridotites and serpentines). Although genetically very interesting these deposits generally have no economic importance.

Crusts of weathering of ultrabasic rocks are formed in arid and wet climates under the action of air, surface and ground waters, and living organisms. In these crusts the following three zones can commonly be distinguished from the surface down (fig. 5):

1. Zone of ochers;
2. Nontronite zone (often nickel-bearing);
3. Zone of serpentine with magnesite.

Under conditions of lateritization of ultrabasic rocks, descending solutions containing carbonic acid leach magnesium from the upper zones of the crust of weathering, transport it in the form of bicarbonate and deposit in fissures and cavities of the lowermost zone, thus forming magnesite stockworks and small nests. Deposits of this type have a rather small vertical extent (10—15 m).

The Halilovskoe deposit on the Urals (USSR) can be taken as the prototype of infiltration magnesite deposits.

On the Balkan Peninsula occurrences of infiltration magnesite have only been observed at two localities: at Goleš (Serbia) and at Gro'ot, near Titov Veles (Macedonia). They resulted from lateritization of Paleozoic ultrabasic massifs, which took place in the Lower Cretaceous.

Although economically uninteresting, infiltration magnesite deposits are of great scientific interest. They convincingly prove that lateral secretion of magnesium from ultrabasic rocks is possible by the action of descending solutions containing carbonic acid even at slightly elevated temperatures. It follows from this that in their

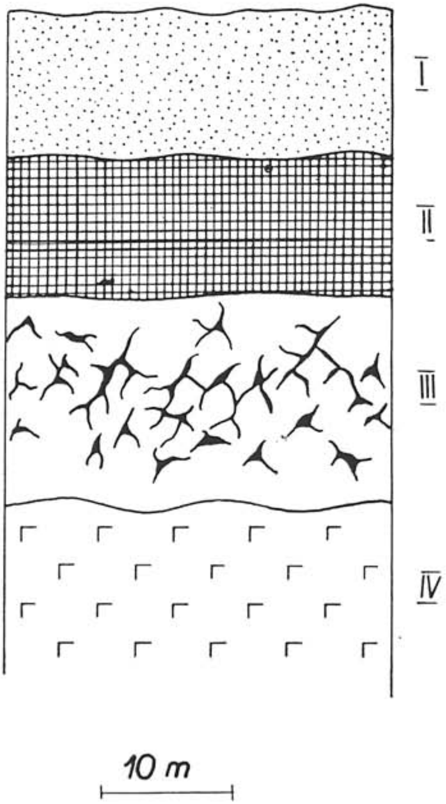

Fig. 5. Diagrammatic presentation of the crust of weathering of peridotite with an occurrence of infiltration magnesite. Legend: I — Zone of ochers, II — nontronite zone, III — zone of serpentinite with magnesite, IV — fresh peridotite.

ascending movement hot juvenile solutions, containing carbonic acid, bring about the same process on a much larger scale.

Conclusions

The above discussion clearly shows that magnesite forms in both the endogenic cycle (hydrothermal deposits) and the exogenic cycle (sedimentary deposits s. str. and deposits resulting from weathering). Besides these, there are transitional hydrothermal-sedimentary deposits.

By taking into account all genetic types of magnesite deposits known so far (including those that have only been observed on the Balkan Peninsula) we were able to set up their new, at present the most complete classification (see Table 1).

Hydrothermal deposits (metasomatic and vein types) and hydrothermal-sedimentary deposits have economic importance. The major part of the world's magnesite production is furnished by deposits of the metasomatic type.

On the Balkan Peninsula deposits of the vein and hydrothermal-sedimentary types are exploited, while metasomatic deposits have not so far been discovered.

Since economically interesting concentrations of magnesite are rarely produced in the exogenic cycle, deposits of this type generally have no practical importance.

REFERENCES

Bain G. W., 1924: Types of magnesite deposits and their origin. Ec. Geol. 19, 5. — Cissarz A., 1956: Lagerstätten und Lagerstättenbildungen in Jugoslavien. Rasprave Zavoda za geol. i geof. istr. NR Srbije 6. — Destombes J. P., 1956: Magnesites (giobertites) des Pyrénées occidentales. Bull. Soc. géol. Fr. 6. 6. — Donath M., 1955: Die jugoslavischen Magnesitlagerstätten. Tonindustrie Zeitung Zbl. 79, 17/18. — Donath M., 1957: Zur Genesis von Lagerstätten dichten Magnesits. N. Jahrb. Min. Abh. 91. — Hiessleitner G., 1934: Zur Lagerstättengeologie des dichten Magnesits in Griechenland und Serbien. Berg. und Hütt. Jb. 82, 1. — Himmelbauer A., 1933: Magnesit. In: O. Stutzer: Die wichtigsten Lagerstätten der Nichterze 5. — Ilić M. sen., 1952: Magnezitsko ležište Bela Stena. Zbornik radova Rud.-geol. fak. 1. — Ilić Miloje, 1964: Genetski tipovi magnezitskih ležišta u zoni ultrabazita Dinarida. Dokt. disert. Rud-geol. fak. Beograd. — Ilić Miloje, 1965: Osnovni geohemijski problemi geneze magnezitskih ležišta. Referati I Simpozijuma SGD iz geohemije, Beograd. — Ilić Miloje, 1966: Genetske odlike magnezitskih ležišta detritičnog tipa. Referati VI Savetovanja geologa SFRJ. — Kazakov A. V., Tikhomirova M. M., Plotnikova V. I., 1957: Sistema karbonatnykh ravnovesii (dolomit, magnezit). Trudy geol. instituta AN SSSR 152. — de Llarena G. J., 1959: Nuevas observaciones solone la magnesita sedimentaria. Estud. Geol. 15. — Martin C., 1956: Origin of crystalline magnesite deposits. Bull. Geol. Soc. Amer. 71, 12. — Nishihara H., 1956: Origin of the bedded magnesite deposits of Manchuria. Ec. Geol. 51, 7. — Petrascheck W., 1931: Die Magnesite und Siderite der Alpen. Sitzgsber. Akad. Wiss. Wien, Math.-nath. Kl. 141. — Petrascheck W. E., 1961: Lagerstättenlehre. Zw. Auf. Wien Springer Verlag. — Petrascheck W. E., 1962: Neue Beobachtungen an griechischen und türkischen Magnesitlagerstätten. Radex-Rundschau 6. — Redlich K. A., 1934: Die Typen der Magnesitlagerstätten, ihre Bildung, geologische Stellung und Untersuchung. Z. prakt. Geol. 42. — Ryzhenko B. N., 1963: Fiziko-khimicheskie dannye po sisteme Me_2CO_3—$MeHCO_3$—CO_2—H_2O i nekotorye prilozheniia k gidrotermal'nomu protsessu. Geokhimiia 5. — Schneiderhöhn H., 1941: Lerbuch der Erzlagerstättenkunde. Verlag G. Fischer, Jena. — Smirnov V. I., 1965: Geologiia poleznykh iskopaemykh. Gosgeoltekhizdat, Moskva. — Strakhov N. M., 1962: Osnovy teorii litogeneza. 3. Izd. AN SSSR, Moskva. — Tatarinov P. M., 1946: Magnezit. Kurs mestorozhdenii poleznykh iskopaemykh. Gostoptekhizdat, Moskva-Leningrad.

Review by B. Cambel.