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The "International Classification of Mineral Resources" in Industrial Minerals Mining

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With 2 figures and 1 table

Summary

Various methods for the classification of mineral resources are applied worldwide. In the past three decades the author used mainly the IMM – "International Standard Classification" and the classification of "Gesellschaft Deutscher Metallhütten- und Bergleute" for the classification of resources of numerous deposits, such as bauxite, bentonite, kaolin, perlite, baryte, base metals and placer gold deposits.

Since 1981, the "International Classification of Mineral Resources" of the United Nations has been used during the assessment of mineral commodities in Europe, Middle East and Asia. The advantages of this new classification method are:

1. The division into reliable – preliminary – and tentative estimates permits the rapid classification of resources. According to the stage of the exploration works and requirements, the resource categories are estimated and expressed as R-1, R-2, R-3 for in situ resources, and as r-1, r-2, r-3 reserves for recoverable quantities.
2. The parallel sets of R- and r- calculations permit the better economic evaluation of a deposit during a feasibility study and during mining.
3. Categories of economically exploitable (E), subeconomic (S) and marginal (M) resouces are indicated for a systematic and comparable subdivision of resources in case of a difficult economic geology, strongly varying mineral content and other constraints calling for a further subdivision of classification categories.

This is demonstrated by an example for the calculation of resources and reserves of one of the largest European perlite deposits.

Zusammenfassung

Verschiedene Methoden der Klassifizierung von Vorräten mineralischer Lagerstätten werden weltweit angewendet. In den vergangenen drei Jahrzehnten hat der Autor hauptsächlich die IMM-„Internationale Standart Klassifizierung", sowie die Methode der „Gesellschaft Deutscher Metallhütten- und Bergleute" angewandt zur Klassifizierung der Ressourcen zahlreicher Lagerstätten wie Bauxit, Bentonit, Kaolin, Perlit, Barit, Buntmetall- und Seifengoldlagerstätten. Seit 1981 ist die „International Classification of Mineral Resources" der Vereinten Nationen bei der Beurteilung von Vorkommen mineralischer Rohstoffe in Europa, Mittlerer Osten und Asien angewendet worden. Die Vorteile dieser neuen Klassifikation sind:

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1. Die Trennung in verläßliche, vorläufige und versuchsweise Schätzungen erlaubt die schnelle Klassifizierung der Vorräte durch einfache Berechnungen mit guter Genauigkeit. Entsprechend dem Stand der Erkundungsarbeiten und des Bedarfsfalles, werden die Vorratskategorien bestimmt und eingeteilt in R-1, R-2, R-3 für in situ Ressourcen und in r-1, r-2, r-3-Reserven für gewinnbare Vorräte.
2. Die parallele Anwendung von R- und r-Berechnungen erlaubt eine bessere wirtschaftliche Bewertung der Lagerstätten im Rahmen einer Durchführbarkeitsstudie und während der bergbaulichen Gewinnung.
3. Eine zusätzliche Unterteilung in wirtschaftlich gewinnbare (E), subökonomische (S) und marginale (M) ist gegeben. Dies erlaubt bei schwierigen lagerstättenkundlichen Verhältnissen, stark schwankendem Gehalt an verwertbarem Mineral etc. die Möglichkeit einer systematischen und vergleichsfähigen Gliederung der Ressourcen.

Dies wird an einem Beispiel der Berechnung der Ressourcen und Reserven einer der bedeutendsten europäischen Perlitlagerstätten aufgezeigt.

1. Introduction

The assessment of a mineral commodity, a mining project or a producing mine deals necessarily with the calculation and evaluation of the resources which form the base and frame of any future investment decision and development.

The resources and reserves are calculated according to various international and national rules, sometimes "adjusted" to the requirements of the companies, and often incorporating ample aspects by the responsible person performing the mineral resource classification.

This leads to the known difficulties and differences in the valuation of deposits and mines and the interpretation of mineral resources data and often renders the figures unsuitable for comparation.

During the past three decades, the author has dealt with the mineral resources evaluation and mine/quarry development of metallurgical and refractory grade bauxite, precious metals, base metals and industrial minerals. The classification methods applied were:

- the "International Standard Classification" according to the rules and recommendations made by the Council of the Institution of Mining and Metallurgy of London.
- The Mineral Resources Classification System of the US Bureau of Mines and US Geological Survey.
- The classification system recommended by the "Gesellschaft Deutscher Metallhütten- und Bergleute".

  This classification method has been introduced since 1961 in Greece by W. E. Petrascheck and the author for the calculation of bauxite resources and reserves. It was further applied since 1965 by the Greek Institute of Geology and Mining Research and the Ministry of Industry to assess the bauxite resources for the first Greek Alumina-Aluminium plant.

  Rules for the calculation of the Greek bauxite resources and classification were summarized in a diagram developed by the author.

- The "International Classification of Mineral Resources" issued in 1979 by the United Nations, Centre for Natural Resources, Energy and Transport, was based on the work of a group of experts on „Definitions and Terminology for Mineral Resources".

  For the application of this method of classification, definitions of the specific requirements for the resources are generally to be established. For various commodities guidelines and rules are to be given, including case studies, to facilitate the application of the new method.

2. Perlite Resources and Reserves

In order to give improved services and to provide perlite qualities to the full satisfaction for an increasing number of customers, the management of „General Enterprises Sarides S. A." under the President of the Company, Leonidas Sarides, decided to proceed to the rebuilding of their perlite grading and processing installations at Tsigrado, Milos Island, Greece.

The quarrying method applied for excavating the raw, loose perlite and the Tsigrado mineral processing plants are designed for a determined range of operating conditions and not for an average condition calculated during the mine assessment. However, the complete modernisation of the perlite quarry and the grading installations required an appraisal of the mineral commodity.

The proper application of the classification presupposes the definition of the mineral commodity to be assessed. For this, a questionnaire or a check list is prepared for each individual mineral commodity.

Due to limited space, only a summary of such basic information for the classification of industrial minerals is given below, namely for the classification of the resources and reserves of one of the most important European perlite deposits.

3. Description of the minerals and general information

Perlite is a glassy igneous rock showing a pearl-like luster and onion-skin structure. The chemical composition is rhyolitic-andesitic, amorphous aluminium silicate containing 3–5 per cent of combined water.

The industry structure has been strengthened during the 50 years perlite is used, and about 2 million tons are mined annually in 20 countries. The main consuming industries are using perlite for light weight aggregates, thermal and acoustical insulation, agricultural and horticultural application, filter aids, cryogenics etc.

Over 50 various specifications of commercial grade perlite are in use varying in different degrees both in granulometric compositions and expanding properties when heated and processed.

Various methods of testing are applied. Some of these methods are cited in the section on recording of samples. Crushing, drying, screening, expanding are the stages of preparing the run of quarry perlite for industrial use.

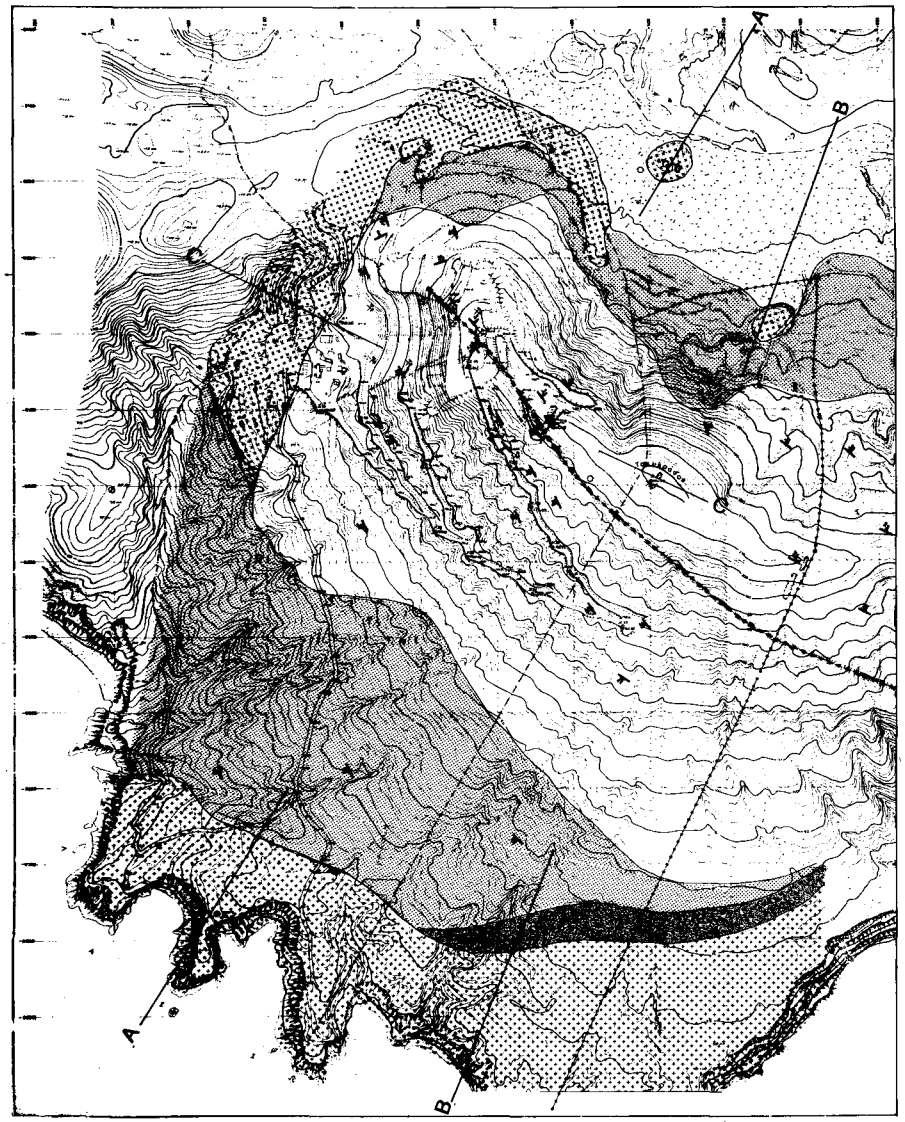


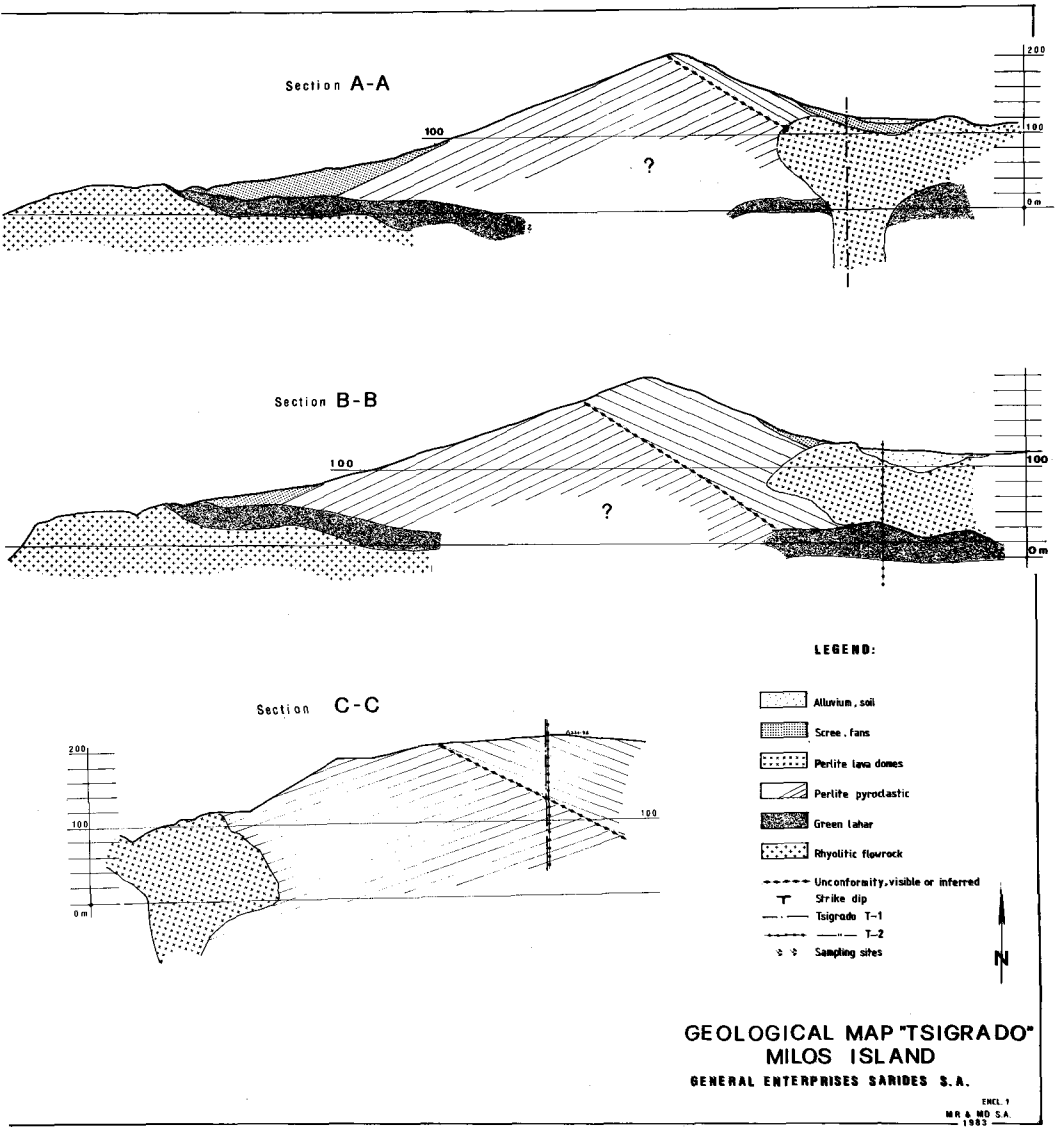
Fig. 1: Geological map with sections, perlite deposit.

4. Occurrence, properties and examination of the perlite

The general geology of the perlite deposit of Tsigrado is shown in figure 1. The mineralogical composition and mineral distribution is mainly restricted to the determination of the percentage of phenocrists in the pyroclastic mass.

For tonnage calculation and computation, geostatistical methods for the quality determination, volume and density of the perlite deposit were applied.

After the appraisal of exploration, mining or quarrying methods and their extent



the cut off grades were determined, mainly characterised by the quantity of not expandable matter.

5. Calculation of the Resources and Reserves

For the calculation of the perlite resources (R) and reserves (r) the "International Classification of Mineral Resources" was applied, (see summary, table 1).

In order to classify as *R-1 (r-1) resources,* the following conditions have to be fulfilled and information be made available:
- Access to the deposit for sampling, from two or three sides. Sampling distances are kept small, at 5–20 m.
- Quality of the perlite is fully examined according to the specifications given below in the sampling procedures.
- Technological properties for grading and expansion of the perlite to be established.
- Quarrying and transportation of the ore to be determined.

After a topographical and geological survey of the Tsigrado deposits the quality determination of the perlite is the most striking task, while quantities are easily computed by using the horizontal sections of the working levels. It was decided to apply a geostatistical evaluation mainly for the r-categories.

For this purpose, great attention must be paid to the proper sampling of the deposit and recording of data. Several hundred samples were drawn, examined and properly recorded.

This work is summarized in the following chapter.

5.1. Recording and Management of Sample Data

Mineral sampling generally is a costly process and has to be made with extreme care.

The final spacing of samples in the Tsigrado perlite deposit is 5 m. A multiple of this distance (10, 15, 20) is applied when starting a new mining level. 20–60 m are selected in horizontal and 10 m in vertical direction at the beginning of the development works.

As minerals population boundaries are selected:
- Physical and topographical boundaries (soil, bedrock, overburden, interfaces, property limits, subsurface limits)
- mineralogical boundaries (gradational boundaries, zonation, foreign rock matter, admixture zones)
- geological boundaries (unconformity line, lava boundary, green lahar layer).

As sampling procedure are applied:
- Channel sampling (CH)
- Chip sampling (CP)
- Muck sampling (MU)
- Bulk sampling (BU)
- Drill hole sampling (DH)
- Core sampling (CO)
- Samples from the grading plant (PL).

Recording of sample data is made to permit the application of a computer based evaluation, by using a 80 column data card.

For the sample identification were selected:
- Tsigrado (TS as identifier for the deposit (or the universe)
- Level to which the samples are attached
- Current numbers of sampless from 001 to 999

- Type and size of sample (CH, CP, MU, DH, PL)

The samples from the grading plant are classified:

0 . . . all grades after the dryer
1 . . . 0.2–0.6 mm
2 . . . 0.6–1.0 mm
3 . . . 1.0–2.2 mm

The size of the sample drawn from the deposit or in the plant (in kg).

The coordinates of samples in 3-D space, recorded as

- Northings
- Eastings
- Elevation.

Quality characteristics of the perlite often depends on the granulometric composition of the run of mine, loose material. Therefore, the measured values and assay results together with the granulometric composition (in situ-accumulative) is indicated in the sample records:

+ 15 mm (15%)
+ 5 mm (35%)
+2.5 mm (45%)
−2.5 mm (55%)

} average values for a medium coarse pyroclastic perlite deposit

The main parameter of the quality of perlite is the bulk density upon heating from 800 to 1050° C. Therefore the bulk density of selected grades after expansion, expressed in g/l, normally of the fraction 0.2–0.6 mm (standard) is used. If other fractions (1.0–2.2) are expanded, the size will be reduced to standard size before expansion. The results of this examination are indicated in the "classifier" of the sample.

Further criteria of quality were the compressive strength of the expanded perlite, and the granulometric composition of the expanded perlite expressed as residue on 16 mesh ASTM screen.

Special properties, such as "soluble iron" of perlite for filter aids, angle of repose and carbon content of perlite for cryogenics and others are normally not examined.

As "other sample classifiers" were used in order to avoid population mixing:

- Relation of sampling site to an existing unconformity line in the Tsigrado deposit. As the direction of this line is generally east-west, the samples are classified by adding N or S.
- In spite of careful overburden removal it may happen that low grade material is included in a sample. Therefore the distance from the stripping surface in horizontal and vertical direction is of interest besides the bedrock admixtures. These admixtures are macroscopically estimated and classified in four categories between "low" and very "high".

With all this quality information in hand, the quantity of R-1 and r-1 resources can be calculated.

The difference between R-1 and r-1 in the perlite deposit of Tsigrado is due mainly to quarrying limitations towards neighbouring properties.

International Classification of Mineral Resources (UN 1979)

Classification categories: R (capital): resources "in situ" of economic interest for the next 2–3 decades; r (lower case): recoverable resources (reserves) closely calculated for mineral supply.

R-1		R-2		R-3 occurrences
Encompasses the *in situ* resources in deposits that have been examined in sufficient detail, sizes and qualities known, technology established. Relevance of such estimates is the **planning of mines.** Error of estimation less than 50%.		Estimates of *in situ* resources that are associated with discovered deposits, quantities are preliminary and largely based upon broad geological knowledge, supported by measurements at some points. Estimation error above 50%. Estimates relevant for **planning of further exploration** for R-1 resources.		Undiscovered *in situ* resources that might exist based on geological extrapolation. R-3 **indicate exploration opportunities,** quantities known in ranges.
– reliable estimates –		– Preliminary estimates –		– tentative estimates –
R-1-E	*R-1-S*	*R-2-E*	*R-2-S*	Not subdivided further
Economically exploitable, believed to be workable with regard to thickness, depth, grade.	"Subeconomic", prefix "sub" denotes under, below, less than normal amount, contain small portions.			
	R-1-M Marginally economic, a deposit near the lower limit of commercial workability which can be exploitable in short due to economic and technical changes.			

The "recoverable resources" are classified accordingly as r-1, r-2, r-3. The definition of recoverability and the point it will be measurd in the exploration, mining and processing sequence must be established for each commodity.

r-1
r-1-E *r-1-S*
r-1-M

r-2
r-2-E *r-2-S*
r-2-M

r-3
not subdivided further

5.2. Calculation of R-2 (r-2) Resources

To classify perlite in this category, the access to the deposit for sampling from one or two sides must exist. Sampling distances are between 20–60 m. The quality determination in general is similar as mentioned under R-1, however, with reduced number of samples.

The examination of samples is not as complete as for R-1 (r-1) resources in order to determine mineralogical, chemical and physical properties, and technological effects from grading and expansion at various temperatures.

No extrapolation was applied in areas where R-1 resources were calculated.

5.3. Calculation of R-3 Resources and Final Remarks

These R-3 resources are calculated by using an extrapolation zone of 20 m below the level 80, the lowest mining level for which R-2 (r-2) resources could be calculated.

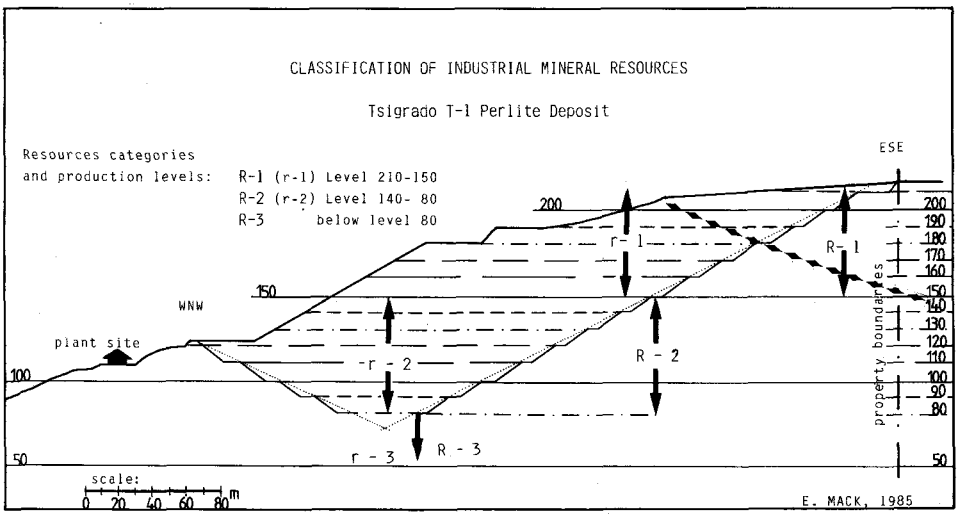


Fig. 2: Resource categories and production levels of the perlite quarry.

The recoverable ore (r) of all categories was calculated as for the corresponding in situ resources (R), under consideration of the loss during extraction by the quarrying method. The loss is here also mainly due to a safety zone at the border line to the neighbouring property.

The relation of reserves to resources in the Tsigrado 1 deposit is:

$$\frac{r-1}{R-1} = \frac{3.5 \text{ mill } t}{4.7 \text{ mill } t} = 0.74$$

$$\frac{r-2}{R-2} = \frac{8.6 \text{ mill } t}{17.7 \text{ mill } t} = 0.48$$

$$\frac{r-3}{R-3} = \frac{0.9 \text{ mill } t}{4.3 \text{ mill } t} = 0.2$$

The geological position, homogenity of the Tsigrado deposits, and the excavation method applied, do not require a subdivision of the reserves and resources into economically exploitable (E), subeconomic (S) and marginal (M) categories as suggested in the International Classification of Mineral Resources.

A result of this calculation of R and r resources and reserves was for the management the intention to have access to the neighbouring area by signing a long-term lease contract. By this, the reserves of the main deposit were significantly increased without further exploration or developing works, providing for many decades to come a safe base for supplying the national and international market with high quality perlite.

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