DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD 1976/74

MINERAL RESOURCE ASSESSMENT

Report by BMR Interbranch Committee

Committee Members

L.C. Ranford (chairman)
R.G. Dodson
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CONTENTS

CONCLUSIONS AND RECOMMENDATIONS

1. Knowledge of the quality and quantity of Australia's mineral resources is essential data for effective management of our land and mineral resources. The knowledge is required to help anticipate possible mineral shortages, to indicate mineral potential where alternative land use is being considered, to establish priorities for geoscience surveys and research and to indicate the need for new Government policy affecting the mineral industry.

2. The assessment of the nation's total mineral resources can be considered in two distinct phases.

(i) the assessment of the identified mineral resources.

(ii) the estimation of undiscovered mineral resources.

3. The assessment of identified resources is the highest priority as the results of this work provide the data necessary for short and medium term planning and also form the foundation for any comprehensive attempt to estimate undiscovered mineral resource potential.

4. Qualitative or quantitative assessment of undiscovered mineral potential should be undertaken concurrently with any comprehensive assessment of total identified mineral resources. The method or methods used and the level of effort assigned to undiscovered potential should be determined on the basis of identified resources and estimated demand.

5. BMR has previously undertaken limited assessments of some of Australia's identified mineral resources and is the logical Government organisation to do this work for most mineral commodities.

6. The assessment of the total mineral resources can be approached on a region by region basis for all commodities or on a commodity by commodity basis. A commodity approach is recommended for BMR because of the priorities which exist for the assessment of certain commodities on a national basis and also the nature of the expertise required for mineral resource assessment.

7. BMR is already carrying out the assessment of Australia's petroleum resources; this assessment capability should be extended to cover other minerals. Some additional skills in the disciplines of metallurgy, geomathematics and economic geology will be required.

8. BMR should establish a number of small commodity oriented Mineral Deposits Study Groups. These groups should study identified mineral deposits including their geological setting, geological, geochemical and geophysical expression and the methods used to explore for them. They would publish information on mineral deposits and they would develop the data base and expertise necessary to undertake periodic mineral resource assessments.

9. BMR should establish a small group to undertake metallurgical investigations. The group would investigate and report on metallurgical practice and technology in Australia and overseas and provide the expertise necessary for detailed resource assessment projects.

10. BMR should establish a small group to specialise in the field of geomathematics and geostatistics. The group would investigate and report on the methodology and take part in multidisciplinary project teams assessing mineral resources. This is a new field and experimental projects designed to predict the occurrence of undiscovered mineral resources would be an important facet of the work.

INTRODUCTION

Most of BMR's scientific effort over the past 30 years has gone into regional geological and geophysical surveys. The objective of these surveys has been to establish, in broad terms, the geological structure and history of the continent; this knowledge is an essential prerequisite for modern methods of mineral exploration. However the dramatic expansion of the Australian mineral industry in the past 10-15 years has resulted in an additional need for data relevant for resource management and policy formulation; in effect, this requires thorough knowledge of the magnitude of known and potential resources.

In recognition of the need to meet this growing requirement, the Director requested that an inter-Branch committee be established to

- review the methodology of mineral resource assessment and recommend how BMR should proceed towards fulfilling the objective of assessing Australia's mineral resources.

Petroleum resources were excluded from the Committee's terms of reference as a petroleum assessment group already exists within BMR.

The Committee was formed at a special meeting of senior staff on 17 February 1976, and met regularly over a 3 month period. Discussion papers were prepared by various committee members and by a number of invited contributors; in addition the Committee sought and received some information from Government agencies in the USA, Canada, and South Africa about their programs and methodology.

The Committee concerned itself with answering the following questions:

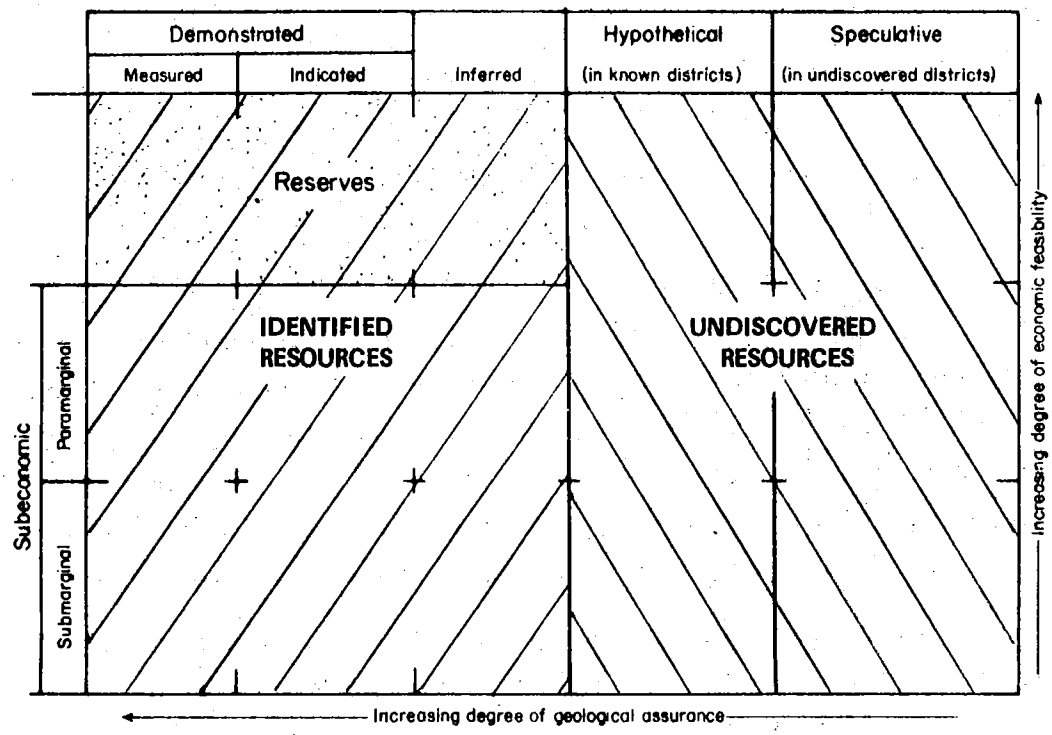
- what is meant by mineral resource assessment and how are resources classified?
- what is the purpose of mineral resource assessment; who will use the results?
- what is involved in carrying out a mineral resource assessment; what are the prerequisites; what is the output?
- what techniques are in use elsewhere in the world to quantitatively assess undiscovered mineral resources?
- what is BMR's present role in mineral resource assessment; what changes, if any, are required to enable it to fulfill the objective of assessing Australia's mineral resources.

TERMINOLOGY

Mineral Resource Assessment is the continuing process of determining the known and potential mineral resources of a region (e.g. Australia) and setting them within the context of mineral resources of the world. The results of this work are progressively reported as qualitative and/or quantitative appraisals.

Figure 1

DIAGRAMMATIC REPRESENTATION OF CLASSIFICATION OF MINERAL RESOURCES



Resource—A concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust and in such form that economic extraction of a commodity is currently or potentially feasible.

Identified resources—Specific bodies of mineral-bearing material whose location, quality, and quantity are known from geological evidence supported by engineering measurements with respect to the demonstrated category.

Reserves—That part of the identified resources from which a usable mineral commodity can be economically extracted at the time of determination.

Inferred—Reserves or resources for which quantitative estimates are based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition, of which there is geological evidence; this evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geological evidence of their presence.

Identified-subeconomic—Known resources that may become recoverable as a result of changes in technological and economic conditions.

Undiscovered resources—Unspecified bodies of mineral-bearing material surmised to exist on the basis of broad geological knowledge and theory.

Hypothetical resources—Undiscovered resources that may reasonably be expected to exist in a known mining district under known geological conditions. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as a 'reserve' or 'identified-subeconomic' resource.

Speculative resources—Undiscovered resources that may occur either in known types of deposits in a favourable geological setting where no discoveries have been made, or in as yet unknown types of deposits that remain to be recognized. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as 'reserves' or 'identified-subeconomic' resources.

(See also Appendix 2 for further discussion of the above resource classification system.)

REQUIREMENT FOR NATIONAL MINERAL RESOURCE ASSESSMENT

Australia has become a major source of raw materials to the industrial nations of the world. Only a very minor quantity of these materials is consumed, or is likely to be consumed in Australia and it is imperative that we recognise the international implications and responsibilities of this mineral endowment. This is especially so at a time when it is generally appreciated that the supply of the natural resources on Earth are finite and may well prove to be a limiting factor in attempts to raise the general standard of living to that currently enjoyed in parts of the industrialised world.

As a result of Australia's relatively small population and apparently abundant resources, there is a growing interest in Australia by resource-poor nations wishing to secure future supplies of essential resources. These nations will be, and indeed are already, undertaking resource assessment programs in Australia and if we are to have an equal knowledge and understanding of our own resources, then such assessments must also be carried out by Australian government advisory bodies.

Although mineral rights are vested in the crown and administered by the respective State Governments, the Federal Government is responsible for overall management, strategic considerations and international trade, and must therefore accept the prime responsibility for ensuring that the nation's mineral resources are wisely managed.

There is a requirement for the Federal Government to ensure that the Australian people receive the maximum possible benefit from the use of these non-renewable resources and that subject to our own strategic requirements, supplies are also made available to the consuming nations. Decisions need to be made on a national level rather than the sectional or regional levels represented by the mineral industry and State authorities respectively.

The national government needs to know the extent and availability of the nation's mineral resources so that it can formulate its policies on the soundest possible basis. To achieve this objective it will be necessary to engage in periodic comprehensive reviews of the nations mineral resources, ranging from accurate assessments of reserves established by the mining industry and future projections of market and consumption trends through to studies of the geological controls on mineralization and their portent for future discoveries.

At present reserves and resources are reported by companies in a form which primarily reflects the individual needs of the companies and their responsibilities to their stock holders. The sum total of the published figures is not necessarily a reliable guide either to the quantity of minerals that have been identified or the economic feasibility of recovering the material reported.

The provision of properly documented and carefully explained quantitative estimates of the identified resources, including the inferred extensions, is the prime data for planners engaged in supply and developmental contracts associated with the mineral industry. It is this information which will provide the confidence necessary to enter into long term supply agreements, for the raising of loans and the establishment of major new infrastructure and industry.

The more easily found and readily worked deposits are rapidly being depleted, and in view of the complex technology, immense capital investment and resultant delay or lead time necessary to find, prove and develop new economic mineral deposits, it is essential for government and the mineral exploration industry to adopt a much longer view than that represented by demonstrated reserves. Consequently there is a growing demand for sound appraisals of undiscovered mineral resources in order to anticipate potential resource shortages, future supply problems, and competing land use requirements; exploration, research, and legislation can then all be directed towards solving these problems before critical situations arise.

THE MINERAL RESOURCES ASSESSMENT PROCESS

The mineral resource assessment process is summarised diagrammatically in Fig. 2. The process can be considered in two distinct parts (Identified Resources and Undiscovered Resources) which are discussed separately below.

IDENTIFIED MINERAL RESOURCES (i.e. demonstrated economic and subeconomic resources, and their inferred extensions)

The compilation and analysis of identified resources involves identifying and classifying all known mineral deposits and prospects including by-product sources. Information necessary for this work includes:

- data on Australia's identified economic and subeconomic mineral deposits
- data on the economic framework of the mineral industry to assess the degree of economic feasibility of mineral deposits
- knowledge of likely new technological developments which may affect the future extraction, production or consumption of mineral commodities.

It is estimated that approximately 70% of this data is held by private mining and exploration companies, although a significant part of the basic data on undeveloped deposits and occurrences is held in State Mines Department files on either a confidential and non-confidential basis. BMR holds some basic data but close co-operation with industry and the State Mines Departments is obviously essential for this work.

Stages in the Assessment of Identified Resources

The assessment of the total identified resources can be subdivided into the following stages:-

STAGE 1 (Assess Reported Demonstrated Reserves)

Procedure: Obtain, classify and aggregate 'reserve' data published by companies and unpublished data made available to BMR during routine discussions. Published 'reserve' data usually do not include inferred reserves, and in the case of some companies do not include all demonstrated reserves. Consequently the total at this stage will comprise most, but not all, demonstrated reserves.

MINERAL RESOURCE ASSESSMENT PROCESS

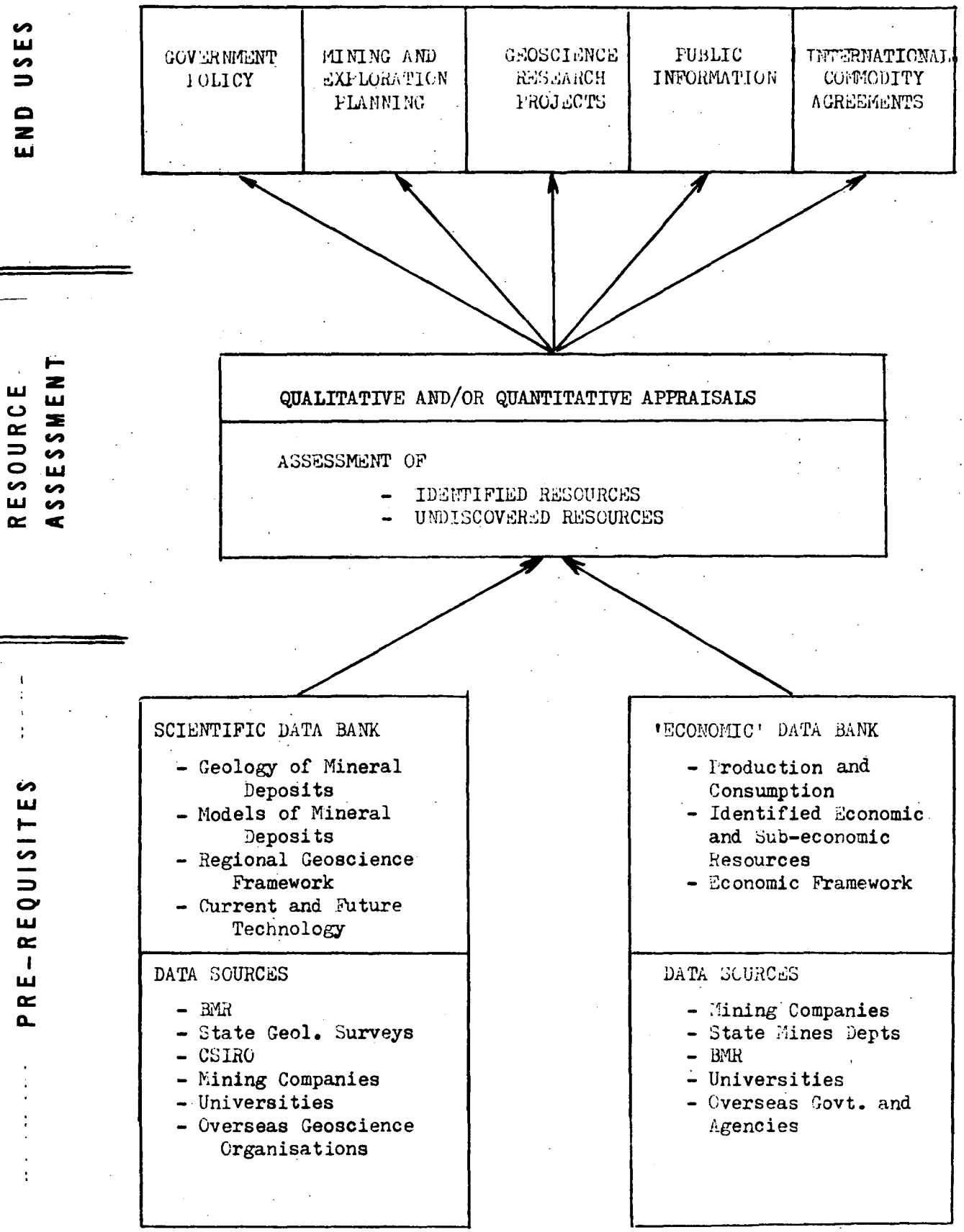


Figure 2

Pre-requisites: Examination of company reports and other published information; routine discussions with companies and understanding of the basis used by each company for its reserve calculation.

Staff: Mineral economists, mining engineers and metallurgists.

Output: Quantitative appraisals of most demonstrated reserves for all significant minerals, plus an indication of supply deficiencies based on existing and planned production schedules.

STAGE 2 (Assess Total Reserves and Identified Paramarginal Resources)

Procedure: Obtain, aggregate and classify published and unpublished data held by companies and State Mines Departments; companies regard unpublished data on mineral deposits as extremely confidential and planning for the work must take this into account.

Pre-requisites: Visit mining and exploration companies; where necessary calculate or recalculate reserves and resources from drilling, mining and assay data; carry out cost studies where appropriate.

Staff: Mineral economists, mining engineers, metallurgists, geostatisticians, and geologists.

Output: Appraisals of total demonstrated reserves plus inferred reserves, and identified paramarginal resources, which will provide appraisals of total known economic and near-economic resources.

STAGE 3 (Assess Total Identified Sub-economic Resources)

Procedure: Identify all known sub-economic occurrences; calculate and classify resources in each significant occurrence.

Pre-requisites: Collect all available data from within BMR, State Mines Departments and companies; where appropriate supplement these data with field work; carry out generalised cost studies.

Staff: Geologists, mining engineers, metallurgists, mineral economists, and geostatisticians.

Output: Appraisals of total identified sub-economic resources, either in a quantitative or a qualitative form, which together with output from Stage 2 will given appraisals of total identified resources.

UNDISCOVERED MINERAL RESOURCES

The estimation of undiscovered resources is a relatively new science which has attracted increasing interest over the last 20 years. The methods used to estimate undiscovered resources range from a mathematical approach with little or no geological basis to the various methods which rely on detailed knowledge of the characteristics of mineral deposits and the geology of the region to be assessed.

The various methods which have been used are briefly outlined below:-

Spatial analysis was the first technique developed. In its simplest form the mineral endowment is assumed to be a function of area only and independant of geology. The mineral wealth per unit area of any particular region is assumed to be the same as that for a well explored control area where the mineral endowment can be easily quantified. This method provides the lowest level of information and should be applied only to obtain broad estimates for regions where knowledge is extremely limited and more refined techniques cannot be applied.

The crustal abundance technique introduced by McKelvey in 1960 is a variant of the spatial analysis method. He found that the identified minable reserves for many elements in the United States were equal to their crustal abundance in percent times a factor of 10^9 or 10^{10}.

The technique is useful for obtaining a minimum total resource estimate for large areas, but the estimate is minimal because the relationship is based on currently recoverable resources and does not include resources whose feasibility of economic recovery is not established.

Multivariate geostatistical analysis is simply a development of spatial analysis and explicitly takes into account geological variables. The relationship between mineral occurrence and geology is established in a control area. The technique may involve quantitative measurement of more than 30 variables such as age and type of host rock, degree of fracturing or faulting, contact relationships, etc, which are related to mineralization. These variables are then measured in the target area which is commonly divided into a number of cells for ease of calculation. The established relationships between mineral occurrence and geology in the control area are assumed to hold in the target area and hence the mineral resources in the target area can be estimated. The technique was pioneered and developed by D.P. Harris in the late 1960's to permit geostatistical analysis and computer simulation.

Subjective probability analysis is in reality a multivariate geostatistical analysis performed mentally rather than by rigid modelling and computer processing. It is the method adopted and used, often subconsciously, by every mineral explorer to assess the mineral resources of a target area. As formalised by Freyman and Barry (1970) and Harris (1973) the method consists of obtaining the best estimates of mineral occurrence from a number of experienced economic geologists who are familiar with the target area being assessed. The most obvious difference between this method and the previous one relates to the control area. The control area for each geologist is the sum of his knowledge on mineral occurrence gained through first-hand personal experience, academic training, reading, discussion with colleagues, etc. There are obvious advantages in making use of such extensive control areas when conducting a resource assessment. However there may also be pitfalls because of personal bias or inadequate experience of the geologists surveyed.

All methods of resource estimation rely either directly or indirectly on the extrapolation of the mineral distribution of a known region (control area) to the area to be assessed (target area). The results obtained by these various techniques will therefore ultimately depend on our knowledge and understanding of known mineral deposits and our knowledge of the geology of the area to be assessed. None of the methods currently in use can be regarded as being clearly superior and the best measure of confidence that we can expect will arise from obtaining similar results from a number of methods.

The assessment of undiscovered resources is a contentious subject. There appears to be general support for the preparation of qualitative appraisals of undiscovered potential so long as the basis of the appraisal and the assumptions made are carefully stated, but there is some opposition to the quantitative expression of undiscovered resource estimates based on the following arguments: (a) there is insufficient understanding of the fundamental processes and controls necessary for ore formation for most minerals, and insufficient knowledge of the geological framework in many areas, so that the estimates will be meaningless; (b) even carefully qualified quantitative estimates may be misused through ignorance or misunderstanding.

The Committee is of the opinion that attempts should be made to assess the undiscovered resources of Australia with a view to producing initially qualitative and eventually quantitative appraisals. An approach based on experimentation with various techniques is favoured, depending on the commodity concerned and the information available. In the short term, some form of subjective probability analysis designed to tap the existing expertise appears to be the most attractive method, but in the long term a form of multivariate geostatistical analysis undertaken by a team of geomathematicians, mineral deposit geologists and regional geologists is considered the best approach to provide quantitative estimates with a minimum of subjectivity.

The information necessary for the assessment of undiscovered resources comes from a wide variety of data sources and includes

- knowledge of Australia's identified resources
- knowledge of the Australian geological, geochemical, and geophysical framework
- knowledge of the geological controls and processes involved in ore formation, based on Australian and foreign deposits and on theoretical models
- knowledge of the exploration history of the region being assessed, including methods used and results obtained.

The favoured methods for the assessment of undiscovered resources rely heavily on expertise in the fields of mineral deposit geology and regional geology with support from other geoscience disciplines. The process can be considered in two stages as outlined below.

Stages in the Assessment of Undiscovered Resources

STAGE 1 (Assess Hypothetical Resources)

Procedures: Identify factors controlling mineralisation in each mineralised district or for each commodity type; predict occurrences of additional mineralisation based on extrapolation of known mineral occurrences in known geological environments.

Pre-requisites: Geological models of Australian mineral deposits; an understanding of the genesis and detailed knowledge of the geological, geochemical and geophysical expression of these deposits.

Detailed geological, geochemical and geophysical information from the mineralised provinces plus a knowledge of the exploration methods and past activity in the provinces.

Staff: Geologists, geophysicists, geochemists and geostatisticians.

Output: Qualitative or quantitative appraisals of hypothetical resources.

STAGE 2 (Assess Speculative Resources)

Procedures: Combine knowledge of the processes and controls which form mineral concentrations with knowledge of the geology of all Australian geological provinces to predict the existence of mineralised districts.

Pre-requisites: Geological models of Australian and foreign mineral deposits; knowledge of the fundamental processes and controls responsible for ore formation.

Knowledge of the geologic framework of Australia including available geological, geochemical and geophysical data which might be used to assess the mineral potential of areas considered to be prospective.

Knowledge of the exploration methods used and past exploration activity in any area considered to be prospective for minerals.

Staff: Geologists, geophysicists, geochemists and geostatisticians.

Output: Qualitative or quantitative appraisals of speculative resources.

REGIONAL VERSUS COMMODITY APPROACH TO RESOURCE ASSESSMENT

Ascertaining the extent of a nation's mineral resources is not a simple matter. The total resources of any one mineral commodity is the sum of many mineral deposits from different geological regions, of different deposit types, and of differing degrees of geological certainty; in addition any appraisal of potential mineral resources may be either qualitative or quantitative. The sum of the resources of all commodities will give the nation's total mineral resources or mineral endowment.

To obtain the total mineral resources of Australia it would be necessary to have expert knowledge of all regions and all commodity deposit types within these regions. It is obviously not physically possible for BMR to study all regions and/or commodities in-depth at any one time. Accordingly priorities will need to be allocated.

There are two fundamental approaches to mineral resource assessment

- on a regional basis in which the emphasis is on evaluating a region's potential prospectivity
- on a commodity basis in which emphasis is on the supply and potential of an individual commodity or group of commodities.

The Committee strongly recommends the latter approach for the reasons outlined below.

By using the regional approach and studying only selected regions, it is not possible to satisfy the national requirement for a total assessment of the resources of any particular commodity. By using the commodity approach, however, it is possible to study high priority commodities on an Australia-wide basis. In addition, problems associated with the estimation and appraisal of mineral commodities are largely specific to individual commodities and it is therefore essential to develop specialist knowledge of these commodities and their modes of occurrence if we are to provide the desired quality of resource appraisal. Finally, it is suggested that a national commodity approach would complement the existing State and Federal regional geoscience programs and is more consistent with BMR's role as the national minerals authority.

MINERAL RESOURCE ASSESSMENT AND THE BMR

In previous sections of this report, we have indicated what is involved in mineral resource assessment and suggested how the process may be tackled in a series of Stages involving different types of expertise. We have also argued that the best approach to determining the total resources is via the individual commodities or natural commodity groups.

Because of the complexity of the Mineral Resource Assessment process and the range of expertise required we suggest that the best means of establishing a resource assessment capability is to set up the various disciplinary groups required with on-going programs designed to provide valuable background information on mineral deposits and the mining industry. These groups would be called on to form multidisciplinary teams as required to complete specific stages of resource assessment. The various disciplinary groups involved with resource assessment are shown in Fig. 3 and the recommended structure for an organization designed to undertake mineral resource assessment is illustrated in Fig. 4. The organization consists of two major groups of commodity specialists (mineral economists and mineral deposit geologists) with small specialist groups in the fields of mining engineering, metallurgical engineering and geomathematics who would team with commodity specialists as required for specific resource assessment projects. The groups shown do not represent all the expertise that may be necessary to assess mineral resources but rather the core which would be capable of undertaking the major part of the activity as defined in this document. Geologists, geochemists and geophysicists working in other fields may well be involved in certain mineral resource assessment teams especially in those projects involved in the assessment of undiscovered resources.

The process of mineral resource assessment is essentially one of compilation, interpretation, analysis and projection. It involves using a great deal of data collected and collated by other specialists and to complete worthwhile national assessments will require the close cooperation of many geoscientists in various Government agencies and private companies. Considering the many and varied sources of data involved and the confidential nature of much of the information which is required, the staff employed on this work should be experienced geoscientists.

CURRENT AND RECOMMENDED BMR ROLE

The BMR already has part of the basic staff requirements necessary to undertake mineral resource assessment (Fig. 4) and has since its inception, been responsible for the compilation on a national basis, of data

Figure 3

INVOLVEMENT OF VARIOUS DISCIPLINARY GROUPS

IN

MINERAL RESOURCE ASSESSMENT

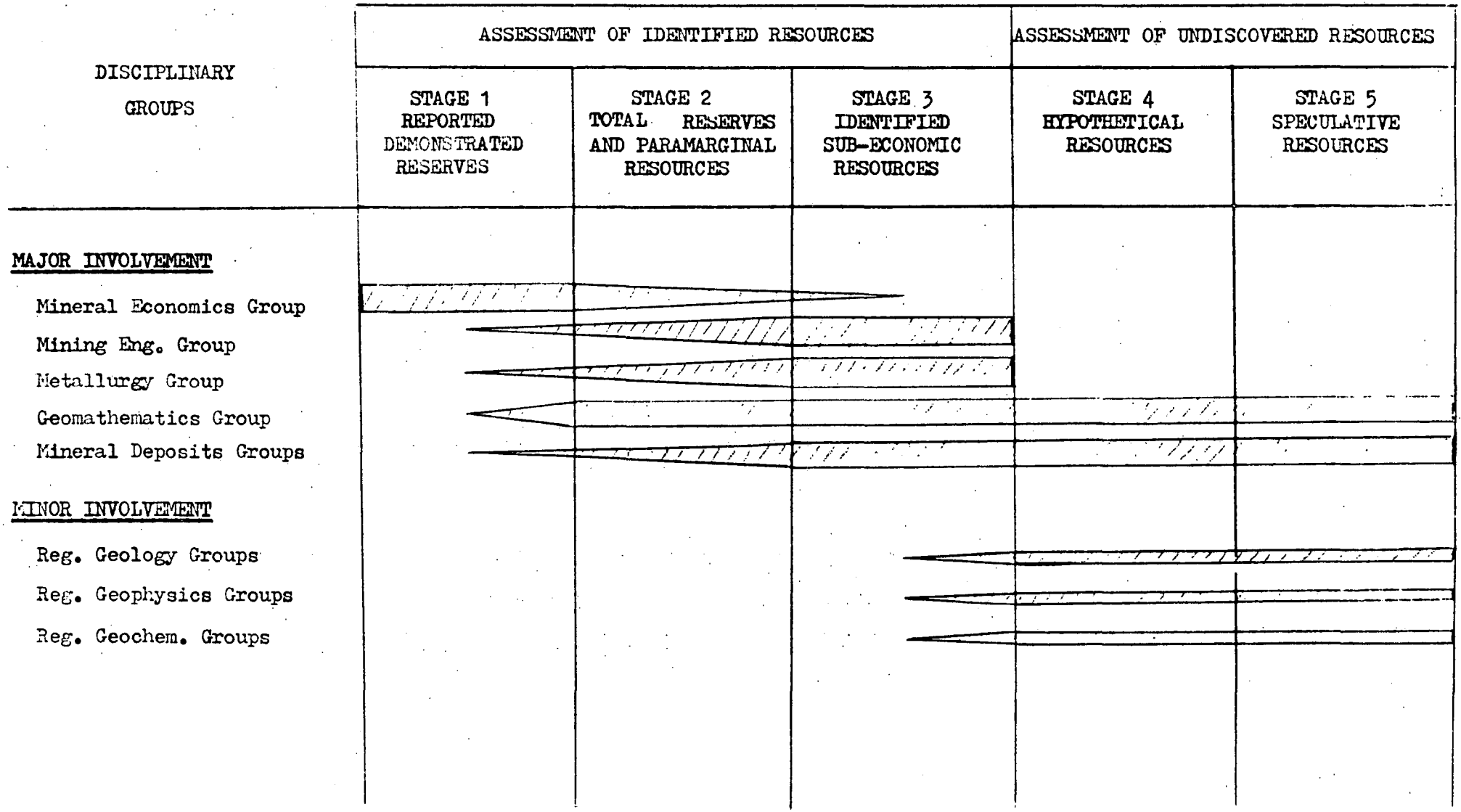
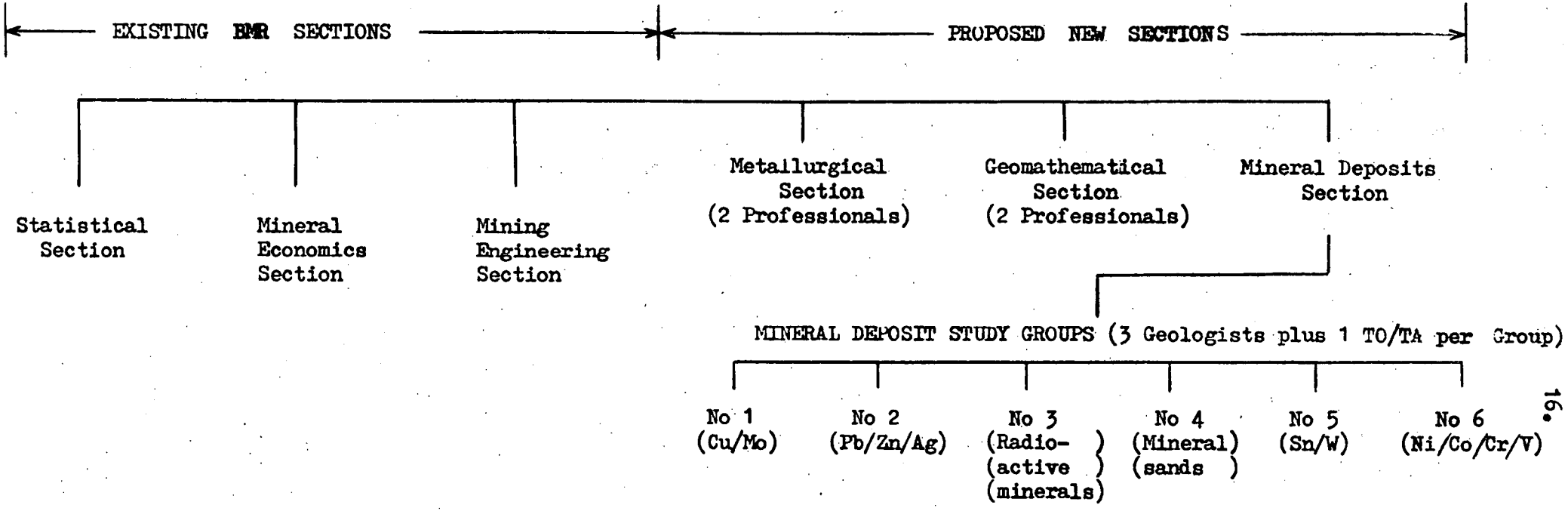


Figure 4

DIAGRAM ILLUSTRATING EXISTING AND PROPOSED SECTIONS WITH MAJOR INVOLVEMENT IN MINERAL RESOURCE ASSESSMENT



NOTE: PROPOSED NEW PROFESSIONAL POSITIONS

SECTION	STAFF SPECIFICATION
1. Mineral Deposits Section	Geologist in charge of each group to have minimum of 10 years relevant experience and other geologists to have minimum of 5 years relevant experience.
2. Geomathematical Section	Staff to have minimum of 5 years experience in geomathematical studies.
3. Metallurgical Section	Staff to have minimum of 10 years experience in metallurgy, metallurgical engineering or chemical engineering.

on Australia's mineral resources. Although BMR work in this field has concentrated on demonstrated reserves, compilations and appraisals have been produced which include all the most significant identified resources of certain minerals such as iron ore, tin, coal, antimony and mineral sands. BMR has also produced a Bulletin (No. 72) and Mineral Resource Reports, which summarize the known mineral occurrences of various mineral commodities in Australia.

However BMR has done very little in the way of comparative studies or appraisals of mineral deposits or seriously attempted to calculate and estimate the nation's identified mineral resources and the undiscovered mineral potential.

It should be noted that while it is possible for existing BMR staff (Mineral Economists and Mining Engineers) to produce annual quantitative assessments of demonstrated reserves of major mineral commodities using mainly published data provided by producers and potential producers, there is insufficient expertise or staff to tackle assessment of inferred reserves or total sub-economic resources of most of the major commodities, let alone attempt the more complex task of assessing undiscovered resources.

In order to expand BMR's capability to undertake worthwhile assessments of the nation's total identified resources and to extend this capability to cover the estimation of undiscovered mineral resources, it is essential to add or develop expertise in the fields of metallurgical engineering, geomathematics and the geology of mineral deposits. It is most important that the staff engaged in the fields of metallurgical engineering and mineral deposit geology are experienced professionals of high repute if they are to gain the confidence and achieve the desired level of cooperation from their counterparts in industry and other government bodies.

Mineral Deposit Study Groups

The Committee recommends the formation initially of six mineral deposit study groups each comprising three geologists with at least one permanent technical assistant to each group. The aim of this structure is to establish some breadth of coverage of the major mineral commodities and ensure each group has some depth in terms of experience.

The formation of mineral deposit study groups, which would be required to compile some form of mineral deposit data bank prior to undertaking any more specialised studies, would provide the data and additional expertise necessary for an assessment of the total identified resources of a given commodity and also provide some of the expertise necessary to tackle the more complex problems of assessment of undiscovered potential.

Some of the ongoing programs of the mineral deposit groups may be joint programs with other groups in BMR and possibly also with private industry and with other Government agencies such as CSIRO and State Surveys. The aim would be to broaden eventually the scope of the mineral deposit groups by increasing the coverage of commodities either by adding new groups or reducing the size of the existing groups, depending on the manpower and money available and the agreed priorities at the time.

A list of possible Mineral Deposit Study Groups, which would be necessary to cover all the major mineral commodities has been compiled (Appendix 1). The list is not meant to reflect overall priorities but it is suggested that the range of expertise covered in the first six groups on the list (copper/molybdenum, lead/zinc/silver, radioactive minerals, mineral sands, tin/tungsten, nickle/cobalt/chrome) together with existing expertise in petroleum (BMR), coal (Joint Coal Board) and water (Water Resources Branch, Department of National Resources) would provide a sound basis for future assessments of the nation's mineral resources.

Metallurgy Group

A small group is required within BMR to investigate and report on metallurgical practice, problems and research, and to provide the expertise necessary for mineral resource assessment.

Future supplies of minerals will come both from new discoveries and identified sub-economic resources. It is in the latter field that the metallurgist and metallurgical engineer will make their contribution and it is only by having expertise in this field that BMR will be able to fully assess the likelihood of technological changes and their impact on the economics of mineral extraction.

Geomathematics Group

A small group specialising in geomathematics and geostatistics is required within BMR to keep up with the rapid development in this science and to help develop methodology for use in reserve and resource estimation.

The calculation of mineral reserves, the estimation of inferred reserves and resources and the estimation of undiscovered resources involve complex mathematical concepts, and quantitative appraisals should be expressed in a form which reflects the certainty or probability of the estimate. This subject, plus the newly developed methods of multivariate geostatistical analysis being used in the estimation of undiscovered resources, require a high level of theoretical mathematical training plus an understanding of mineral deposits and the processes which form them. It is essential that BMR employs and develops a specialised geomathematical capability if we are to make effective use of the work currently being produced by industry, academics and other Government agencies such as the Canadian Department of Mines and Energy, and the United States Geological Survey.

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MINERAL DEPOSIT STUDY GROUPS

The following list of mineral deposit study groups has been compiled to illustrate what would be desirable to cover the full range of minerals of economic interest. The various elements, minerals and chemicals have been grouped because of their natural associations either in terms of genesis or their industrial applications.

The BMR already has the equivalent of a petroleum study group and some other groups such as coal and water are also being investigated by other Federal Government agencies.

Construction materials comprise a group which have specialised local interest and would probably be better handled by the appropriate State or Local Government authority rather than a national authority such as the BMR.

The first six groups on the list are suggested as being the most suitable for initial BMR study.

1. Copper, Molybdenum
2. Lead, Zinc, Silver, Cadmium
3. Radioactive Minerals
4. Mineral Sands Group
5. Tin, Tungsten
6. Nickel, Chromium, Cobalt, Vanadium
7. Iron Ore, Bauxite, Manganese
8. Petroleum
9. Coal
10. Fertilizer Minerals and Chemicals
11. Pegmatite Minerals (Colombium, Tantalum, Lithium, Beryllium)
12. Gemstones (Opal, Diamond, Commercial Sapphire)
13. Precious Metals (Gold, Platinum, Palladium)
14. Industrial Minerals Group (Asbestos, Clays, Sillimanite, Kyanite, Graphite, Pumice, Diatomite, Talc, Magnesite, Limestone, Dolomite)
15. Mercury, Arsenic, Antimony
16. Water
17. Construction Materials

BMR Adopts New System of Resource Classification

Minerals are a fundamental component of the nation's material wealth and in order to ensure adequate supplies and to plan for the most beneficial use of the minerals available, governments must have accurate assessments of the quantities already known to exist, and estimates of the quantities that can reasonably be predicted to occur. The amount of a mineral commodity available for exploitation by man is usually expressed as the reserves or resources of the commodity. However, these terms have been and are used in different ways despite numerous attempts to standardise the usage.

To provide a sound framework for the classification of data obtained during resource assessments which it is undertaking, BMR has adopted a system of nomenclature similar to one recently adopted by the US Bureau of Mines and the US Geological Survey. In the new classification the total resources (or mineral endowment) include all materials that have present or future value, and comprise identified (discovered) materials plus those not yet discovered but which are presumed to exist on the basis of geological evidence. They are subdivided according to two parameters: degree of knowledge of occurrence (degree of geological assurance) and degree of economic feasibility of exploitation (Figure 1). The term 'reserves' is used for that part of the total resources that has been identified and can be economically extracted at the time of classification.

The new classification has a much greater scope than the one recommended by the Joint Committee on Ore Reserve Terminology of the Australasian Institute of Mining and Metallurgy and the Australian Mining Industry Council and also differs from it in that 'inferred' material will be included as part of reserves for BMR regional commodity assessments. This is because in terms of geological assurance, the 'inferred' category belongs with the identified sub-divisions rather than with the unidentified 'hypothetical' and 'speculative' sub-divisions. However, when showing total reserves available, BMR will separate totals for inferred material from those for measured and indicated (demonstrated) reserves.

Reserves or resources which are not available for development at the time of classification because of legal or land-use factors will be classified disregarding these factors, but where possible the amount of the total in each category which is affected by such factors will be stated.

The definitions adopted by BMR are given below.

Resource—A concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth's crust and in such form that economic extraction of a commodity is currently or potentially feasible.

Identified resources—Specific bodies of mineral-bearing material whose location, quality, and quantity are known from geological evidence supported by engineering measurements with respect to the demonstrated category.

Undiscovered resources—Unspecified bodies of mineral-bearing material surmised to exist on the basis of broad geological knowledge and theory.

Reserves—That part of the identified resources from which a usable mineral commodity can be economically extracted at the time of determination.

Measured—Reserves or resources for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drill holes and for which the grade is computed from the results of detailed sampling. The sites for inspection, sampling, and measurement are spaced so closely and the geological character is so well defined that size, shape, and mineral content are well established. The computed tonnage and grade are judged to be accurate within limits which are stated, and no such limit is judged to be different from the computed tonnage or grade by more than 20 percent.

Indicated—Reserves or resources for which tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on geological evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to permit the mineral bodies to be outlined completely or the grade established throughout.

Demonstrated—A collective term for the sum of measured and indicated reserves or resources.

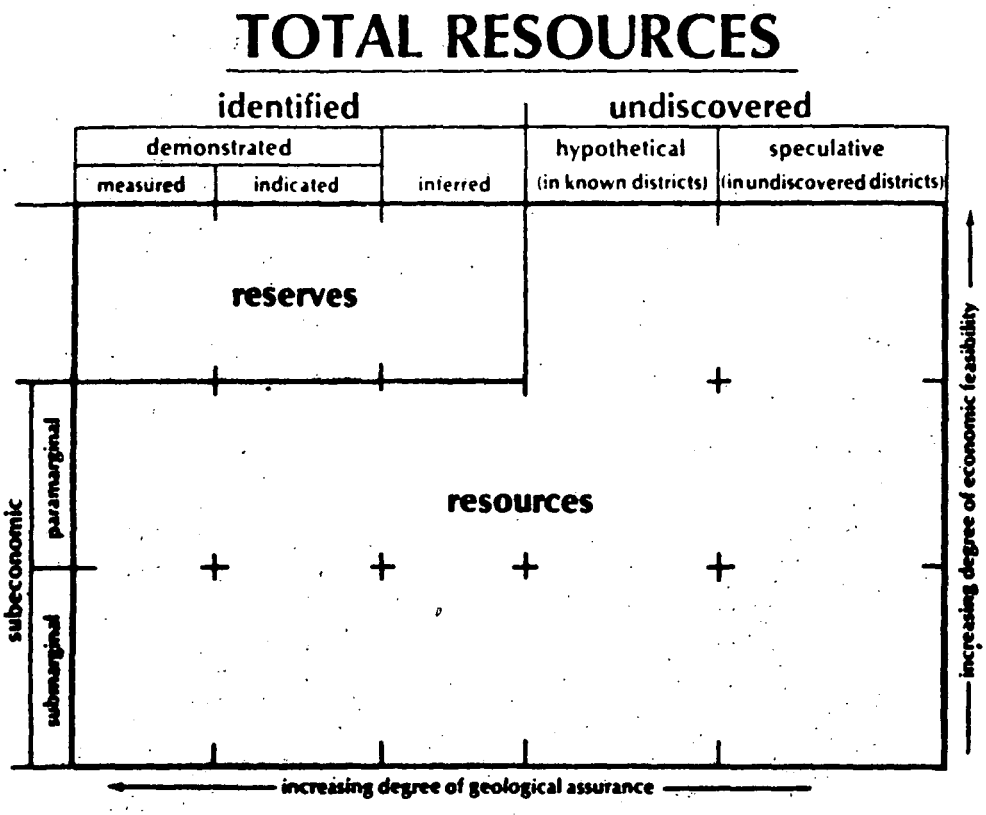

Fig. 1. DIAGRAMMATIC REPRESENTATION OF CLASSIFICATION OF MINERAL RESOURCES

Inferred—Reserves or resources for which quantitative estimates are based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition, of which there is geological evidence; this evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geological evidence of their presence. Estimates of inferred reserves or resources should normally be stated separately and not combined in a single total with measured or indicated reserves or resources, and should include a statement of the specific limits within which the inferred material may lie.

Identified-subeconomic—Known resources that may become recoverable as a result of changes in technological and economic conditions.

Paramarginal—The part of subeconomic resources that borders on being economically producible.

Submarginal—The part of 'subeconomic resources' that would require a substantially higher price (e.g. more than 1.5 times the price at the time of determination) or a major cost-reducing advance in technology.

Hypothetical resources—Undiscovered resources that may reasonably be expected to exist in a known mining district under known geological conditions. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as a 'reserve' or 'identified-subeconomic' resource.

Speculative resources—Undiscovered resources that may occur either in known types of deposits in a favourable geological setting where no discoveries have been made, or in as yet unknown types of deposits that remain to be recognized. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as 'reserves' or 'identified-subeconomic' resources.