PUBLIC GEOLOGICAL SURVEYS in Australia

ABARE report for the Department of Industry, Tourism and Resources

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foreword

Australia is a leading world producer and exporter of several mineral commodities. For example, in 2001-02, Australia’s exports of minerals and metals were valued at $44.8 billion and net petroleum exports were valued at a further $2.6 billion.

Australia is currently experiencing a major downturn in mineral exploration which, if sustained, will have important implications for future mineral production and exports. In September 2002 the Australian government announced the Mineral Exploration Action Agenda, to develop a clearly defined strategy for increasing exploration activity to underpin the future growth of Australia’s mining sector. The agreed framework will contain recommendations for action by industry and government.

The objective in this study is to examine economic aspects of the public geological surveys, particularly the provision of basic geoscientific information that may be used as a key input to private mineral exploration activity. Basic geoscientific information is a public intermediate good that reduces private mineral exploration costs and risks, and increases industry economic rent. Mineral royalty arrangements are a key mechanism for financing the activities of the public geological surveys that directly benefit the minerals and petroleum industries.

This study was commissioned by the Australian Department of Industry, Tourism and Resources to support the Mineral Exploration Action Agenda. A preliminary report was provided to the Strategic Leaders Group in January 2003 for use in the Mineral Exploration Action Agenda process.

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summary

The objective in this study is to examine economic aspects of public geological surveys in Australia, particularly the provision of basic geoscientific information that may be used as a key input to private mineral exploration activity.

Geological surveys undertaken by federal, state and territory governments provide basic geoscientific information that is used by private explorers in selecting a target area for more detailed exploration. While geoscientific information has been acquired mainly to support mineral resource exploration, an increasingly important aspect of all geological surveys in Australia is to support sustainable land resource management, with a recent major focus on dryland salinity. Geological information is also used in the planning and development of infrastructure.

There have been substantial changes in the technologies used to underpin the geological surveys. A key issue for future geological surveys is research and development into, and the adoption of, new technologies that enable exploration of the subsurface geology.

Empirical evidence on the impact of public geological surveys on the timing and location of private mineral exploration activity in Australia tends to indicate that private exploration activity increases in areas whenever new public mapping commences.

As a consequence of historical public and private exploration activity, Australia is a major world producer of several mineral resources, including bauxite, base metals (copper, lead and zinc), coal, gold, iron ore, nickel and diamonds. However, exploration is an ongoing activity that is required for the continued discovery and extraction of mineral resources, and is particularly important for resources such as gold and base metals.

Economic rationale for public geological surveys

Governments invest in basic geoscientific information to facilitate exploration investment by industry. The public provision of geoscientific information reduces both the costs and risks of private mineral exploration.
Public geoscientific information allows private explorers access to information about the regional geological framework at lower cost than would otherwise be the case.

Public geoscientific information reduces the geological risks involved in private sector decisions on which areas to target for more detailed exploration.

From an industry perspective, the benefits of this basic geoscientific information provision should accrue to private companies in the form of increased profit or economic rent. Assessments of location and technology options in the public geological surveys should be based on the expected net economic benefits of each option.

**Box 1: Key findings**

- Mineral exploration is the process of finding and assessing the characteristics of mineral deposits.
  - **Regional mapping** undertaken by public geological survey organizations is an investment in knowledge about the geology of the continent at a regional scale.
  - **Private mineral exploration expenditure** is an investment in knowledge about the location, size and quality of mineral deposits — private explorers invest in mineral exploration based on an assessment of the expected profitability of such an activity, taking into account the various geological, economic and policy risks.

- The public provision of basic geoscientific information increases private mineral exploration activity by reducing both the costs and risks of private explorers in the selection of areas for more detailed exploration.

- Assessments of location and technology options in the public geological surveys should be based on the expected net economic benefits of each option, possibly using breakeven analysis whereby an option is considered to be cost effective if the assessed benefits exceed the identified costs.
  - **Direct economic benefits** accrue to the minerals industry (increased industry profits) and government (increased mineral royalty payments), as well as to other users of the information.
  - **Indirect economic benefits** should also be taken into account and may include contributions to regional and remote economies.
  - **The costs of financing** the public geological surveys should be considered, including any distortions associated with financing mechanisms. Mineral royalty payments may be interpreted as financing the activities of the public geological surveys that directly benefit the minerals industry, taking into account benefits to other users of the information.

continued
Resource taxation or mineral royalty arrangements aim to capture some part of the industry economic rent. The payments received by governments under these arrangements represent a return to the community for the private use of the resource as well as a mechanism for financing the public geological surveys (and other relevant public information programs such as economic market and policy analysis), taking into account other users of the information.

Based on information from the Prime Minister’s Science, Engineering and Innovation Council, the mineral exploration budgets of the public geological survey organisations in Australia in 1999-2000 are reported to have been around $75 million. To provide some context, this compares with total mineral royalty payments to Australian governments of $0.9 billion (excluding petroleum) and $2.4 billion (including petroleum).

**Box 1: Key findings continued**

- In 1999-2000, the mineral exploration budgets of the public geological survey organisations in Australia were around $75 million, compared with mineral royalty payments to Australian governments of $0.9 billion (excluding petroleum) and $2.4 billion (including petroleum).

- Overall, the public provision of geoscientific information is highly likely to have facilitated the efficient discovery and extraction of Australia’s mineral resources. There are a number of areas, however, where there may be potential to improve the efficiency of public and private mineral exploration outcomes.
  - Public geological survey organisations may consider using more formal mechanisms for assessing the expected and realised net economic benefits of regional mapping and information dissemination initiatives (including location and technology options).
  - Surveying industry users is an approach that may be used to inform the public geological survey organisations on the expected benefits of proposed initiatives in public geoscientific information provision. The minimum level of information from this approach would be to rank options based on industry feedback.
  - Undertaking a systematic assessment of the impact of the activities of the public geological survey organisations on private mineral exploration and any flow-on activities, particularly mineral production, would provide information on realised net economic benefits and potentially inform assessments of future initiatives.
  - All private explorers potentially benefit from access to basic geoscientific information. The extent to which industry economic rent increases as a consequence of the public geological surveys is influenced by the efficiency of the mechanisms adopted by governments in assigning mineral exploration rights to individual private explorers.
(excluding petroleum) and $2.4 billion (including petroleum) in 1999-2000.

Overall, the basic geoscientific information provided by the public geological survey organisations results in increased private mineral exploration activity — likely to flow on to higher levels of mineral production, processing and exports — and increased industry economic rent. Anecdotal evidence suggests that public geological surveys have widespread support within industry and are an important source of Australia’s competitive advantage in mining and mineral processing activities.

**Future research directions**

The optimal conduct of public geological surveys in Australia implies that basic geoscientific information for use in private mineral exploration activity is provided at its most efficient (or optimal) level. To the extent that there may be sources of efficiency gains in the public geological surveys — for example, through location and technology choices in regional mapping — it follows that there exists the potential to improve the efficiency of private mineral exploration outcomes in Australia (all else constant).

In this study, the economic rationale for public geological surveys is examined, and key economic issues relating to the efficient conduct of the surveys are identified and briefly discussed. A detailed economic assessment of policy options associated with public geological surveys is beyond the scope of the current study, but some suggested directions for further research are:

- undertaking a systematic assessment of the economic impacts of regional mapping programs in Australia, with a particular focus on identifying key determinants of successful programs and discussing implications for future regional mapping programs;
- undertaking an economic assessment of technology adoption in the public geological surveys, with a particular focus on new exploration technologies; and
- examining mechanisms to formalise industry feedback on the timing and location of regional mapping and other policy initiatives by the public geological survey organisations.
introduction

Australia is a leading nation in the production and export of several mineral commodities. For example, Australia’s exports of minerals and metals were valued at $44.8 billion in 2001-02, representing 29 per cent of total exports of goods and services (ABARE 2003a). Australia’s net petroleum exports were valued at a further $2.6 billion in 2001-02.

Private mineral and petroleum exploration expenditure is an investment in knowledge about the location, size and quality of mineral deposits or petroleum fields. Exploration is an ongoing activity that is required for the continued discovery and extraction of mineral resources.

Australia is currently experiencing a major downturn in private mineral exploration activity (figure A). Private mineral exploration expenditure in Australia (excluding petroleum and in 2000-01 prices) was $0.6 billion in 2001-02, 49 per cent below the most recent peak of $1.2 billion in 1996-97 and the lowest level recorded since 1978-79 (ABS 2003). The downturn is largely associated with reduced spending on exploration for gold, base metals (copper, lead, zinc) and nickel, although private exploration expenditure also declined over this period for coal and uranium, diamonds and iron ore.

Based on survey information released by the Metals Economics Group (MEG), the recent downturn in mineral exploration in Australia has coincided with a substantial fall in global nonferrous exploration (see www.metalseconomics.com). Australia’s share in global nonferrous exploration expenditure declined from 19.1 per cent in 1991 to a low of 16.7 per cent in 1997, but has since increased slightly to 17.6 per cent in 2002 (assuming the ‘origin unknown’ category is allocated equipportionately to all regions). There has been considerable variation in the experience of
individual countries or regions over the past decade — most notably, there was a substantial increase in the share for Latin America (10.8 per cent in 1991 to 25.8 per cent in 2002) and falls in other major regions including Canada (23.3 to 18.3 per cent), the United States (18.5 to 7.2 per cent), Africa (17.1 to 14.8 per cent) and the Pacific/south east Asia (6.8 to 4.9 per cent).

Both international and domestic factors have contributed to the recent downturn in mineral exploration activity including:

- reduced demand for minerals and metals, mainly associated initially with the economic downturn in Japan and other Asian countries and, more recently, with lower economic growth rates in OECD member countries;
- official gold sales by major central banks since 1997;
- the ‘merger wave’ among international minerals companies since 1997 that has resulted in a rationalisation in exploration budgets; and
- increased land access difficulties in Australia, associated most importantly with native title issues over the past decade.

In December 2002, ABARE released a study on private mineral exploration activity in Australia (Hogan et al. 2002). The three major parts to that report covered:

- **trends** — places the recent exploration downturn in Australia in an international and historical context;
- **economic impacts** — quantifies the economic linkages between gold exploration and production, and the flow-on benefits of mineral production to the national, state and territory economies; and
- **policy issues** — examines land access and taxation issues that significantly influence private mineral exploration in Australia.

More recently, ABARE released a study that provides a more detailed assessment of taxation and venture capital financing issues for junior exploration companies (Maritz 2003). ABARE is also currently undertaking further research on native title issues in Australia.

The objective in this study is to examine economic aspects of public geological surveys, particularly the provision of basic geoscientific information that may be used as a key input to private mineral exploration activity.

In recent decades, federal, state and territory governments in Australia have maintained geoscientific databases that comprise survey information undertaken by the public sector (typically at a regional level) as well as more detailed information gained from private exploration activity.

Public geoscientific information is most highly valued in the initial or generative stage of private exploration activity (Williams and Huleatt 1996). In the generative stage, companies identify areas that are considered to be prospective for target minerals using public geoscientific information and supplementary private reconnaissance work. Private companies
subsequently acquire an exploration lease for the targeted areas to undertake more detailed exploration.

Although difficult to quantify, the public provision of geoscientific information has an important role in facilitating the efficient discovery and extraction of Australia’s mineral resources. The public provision of geoscientific information — often referred to as precompetitive geoscientific information — reduces private exploration costs and risks, and enables explorers to select an area for more detailed exploration using all publicly available information from historical exploration activity.

Technology adoption is an important element in the conduct of public geological surveys:

- the first generation geological mapping program was underpinned by the four wheel drive vehicle and aerial photography, with maps first appearing in 1951;
- the second generation geological mapping program commenced in 1990 and was underpinned by technologies such as airborne geophysics and seismic surveys; and
- a key issue for future public geological surveys is the adoption, and financing, of the next generation of mineral exploration technologies — such as CSIRO’s Glass Earth project — that enable exploration at greater depths than was previously feasible.

In the next chapter, background information is provided on the geological surveys undertaken by the federal, state and territory governments, and the Mineral Exploration Action Agenda process that has developed a set of recommendations to facilitate future mineral exploration activity in Australia. The empirical evidence of the impacts of public geological surveys on private mineral exploration in Australia is briefly reviewed in chapter 3. The economic argument for public geological surveys is discussed in chapter 4, followed by a discussion of some key issues in the final chapter.
policy setting

In Australia, mineral resources are owned by the community and government manages those resources on behalf of the community. The Australian government is responsible for oil and gas resources located offshore outside the three mile territorial sea limit as well as for uranium resources in the Northern Territory. State and territory governments are responsible for all other mineral resources located in their respective jurisdictions.

Each government allocates exploration and production rights to the private sector. Mineral royalties are paid to the federal, state and territory governments to provide the community with a direct return on the extraction of mineral resources.

Each government also conducts public geological surveys to provide private mineral and petroleum explorers with basic geoscientific information. In this chapter, some background information on public geological surveys is provided and the Mineral Exploration Action Agenda is outlined.

Public geological surveys in Australia

The Australian government established Geoscience Australia — formerly AGSO—Geoscience Australia, AGSO (Australian Geological Survey Organisation) and BMR (Bureau of Mineral Resources, Geology and Geophysics) — in 1946 to facilitate the national development of mining industries. The organisation was charged with the responsibility of mapping the continent to provide a basis for resource discovery and establishing the mineral and petroleum resource inventory of the nation. Together with state and territory geological survey organisations, Geoscience Australia has developed a series of geological and geophysical maps from continental to regional scale for use in private mineral exploration activity (PMSEIC 2001).

The first generation geological mapping program was underpinned by two technological advances — the four wheel drive vehicle, providing access to the field, and aerial photography, permitting rapid regional geological interpretation (Williams and Huleatt 1996 – information in the following paragraphs also draws on this paper). The maps, which first appeared in 1951, covered 94 per cent of Australia by 1990 when first generation mapping ceased. Reconnaissance mapping (‘first generation’ or ‘first pass’ mapping) of the continent provided 1:250 000 scale data. Around half of these maps resulted from Geoscience Australia (BMR) or joint federal–state operations.

With the emergence of new exploration technologies, it was recognised in the mid to late 1980s that the first generation maps were becoming obsolete. In a review of BMR, Woods...
(1988) recommended a National Geoscience and Mapping Accord (NGMA) between federal, state and territory governments to accelerate a second generation geological mapping program.

The NGMA was established in 1990 to produce second generation geological maps, datasets and related information of Australia. NGMA mapping is underpinned by modern technologies, particularly airborne geophysics and seismic surveys. In particular, airborne geophysics was assessed to be a cost effective approach to rapidly increasing knowledge about Australia’s surface and subsurface geology. Second generation NGMA maps first appeared in 1992. Geophysical mapping (airborne magnetics and gamma-ray spectrometric surveys), gravity and seismic surveys have largely been the responsibility of Geoscience Australia.

The Geological Survey of Western Australia indicates that the current surface geological mapping phase focuses on producing regional scale geological maps and reports, providing 1:100 000 scale data (Guj and Blight 1999). Rogerson (2000) indicates that industry prefers maps providing 1:50 000 scale data — the scale provided in urban resources maps.

In 2000 the NGMA was replaced with the National Geoscience Agreement (NGA). The agreement is designed to avoid any duplication of effort between Geoscience Australia and the state and territory geological survey organisations. Under the NGA, Geoscience Australia contributes specialist activities in support of the states and the Northern Territory. A major focus of the NGA is the development and delivery of high quality geoscience information built around uniform standards and the use of web based information technology (AGSO 2000).

While geoscientific information has been mainly acquired to support mineral resource exploration, an increasingly important aspect of all geological surveys in Australia is to support sustainable land resource management. That is, digital geoscientific maps and datasets are also used for land resource and environmental management, with a recent major focus on dryland salinity. For example, Geoscience Australia in collaboration with the Bureau of Rural Sciences (BRS) and the Cooperative Research Centre for Landscape Evolution and Mineral Exploration (CRCLEME) is undertaking a major program that uses advanced airborne geophysical surveys with integrated landscape and regolith studies to provide salinity risk maps for river catchments. Geoscientific maps and other information are also used in infrastructure planning and development.

The main focus in this report is on the geoscientific mapping program activities of the federal, state and territory geological survey organisations. Australia’s main organisations for minerals research and development, and innovative exploration technologies, are described in PMSEIC (2001). The PMSEIC report also provides several recommendations for future directions in mineral exploration research and development in Australia.

The mineral exploration budgets of geological survey organisations in 1999-2000 are reported in PMSEIC (2001) to have been around:

- $17 million for mineral exploration related work by Geoscience Australia, out of a total budget of $62 million; and
$58 million for mineral exploration related work by the state and Northern Territory geological survey agencies.

Lambert (1999) estimates that since 1990 expenditure under the NGMA was around $350 million — $100 million by the Australian government and $250 million by the state and territory governments. Jaques, Jaireth, Evans, Miezitis and Huleatt (2001) provide more recent data and estimate that since 1990 the federal, state and territory governments have spent around $420 million on the latest geoscientific mapping initiatives.

Over the past decade, there have been several major initiatives by federal, state and territory governments to generate higher quality geoscientific information using updated geological knowledge and technologies. Information on the public geological surveys is provided on the following websites:

- **Australian government** — see www.ga.gov.au for Geoscience Australia;
- **Western Australia** — see www.doir.wa.gov.au for the Department of Industry and Resources;
- **Queensland** — see www.nrm.qld.gov.au for Natural Resources and Mines;
- **Northern Territory** — see www.dbird.nt.gov.au for the Department of Business, Industry and Resource Development;
- **New South Wales** — see www.minerals.nsw.gov.au for the Department of Mineral Resources;
- **Victoria** — see www.nre.vic.gov.au for the Department of Primary Industries (formerly the Department of Natural Resources and the Environment; note that the web site address may change reflecting the change in department structure);
- **South Australia** — see www.pir.sa.gov.au for Primary Industries and Resources; and
- **Tasmania** — see www.mrt.tas.gov.au for Mineral Resources Tasmania which is a division of the Department of Infrastructure, Energy and Resources.

Geoscience Australia (see Jaques et al. 2001) has argued that there is significant potential for new mineral discoveries in Australia, particularly at depth, including:

- extensions of known mineral provinces;
- existing provinces for known mineral deposit styles; and
- new provinces for mineral systems known from other provinces.

Geoscience Australia also indicates that there is potential for new mineral systems in Australia. In addition to government mapping initiatives (particularly the regional high resolution geophysical surveys) and continued research efforts, future discoveries would be assisted by the adoption of new generation exploration technologies. The timing of the adoption of such technologies, and associated financing, are significant issues that will need to be addressed by the public geological survey organisations over the short to medium term.
Mineral exploration action agenda

Action agendas are a key element of the Australian government’s industry policy (Commonwealth of Australia 2002). They are designed to build a dynamic partnership between industry and government, with the goal of promoting sustainable economic growth.

Action agendas for specific industries are considered where:

- a ‘whole of government’ approach is required to address impediments to growth in a particular sector;
- the industry represents, or may in the future represent, a substantial aggregation of economic activity or is a driver of growth in other sectors;
- significant opportunities or market impediments exist;
- there are substantial pressures for structural adjustment; and
- the industry has some demonstrated comparative/competitive advantage.

The Mineral Exploration Action Agenda was announced on 12 September 2002 by the Hon. Ian Macfarlane, Minister for Industry, Tourism and Resources (Macfarlane 2002). The key objective in the action agenda is to develop a clearly defined strategy for increasing exploration activity to underpin the future growth of Australia’s mining industry.

The development of the Action Agenda is being progressed by the Strategic Leaders Group (SLG), which includes key representatives from industry and government. The Department of Industry, Tourism and Resources provides the secretariat support for this Action Agenda.

Under the Strategic Leaders Group, four working groups were established to examine priority issues impacting on the level of mineral exploration in Australia:

- access to land;
- access to finance;
- access to precompetitive geoscience information; and
- access to human and intellectual capital.

Each working group drew on expertise from the Strategic Leaders Group as well as the wider mineral exploration community to examine these issues, and develop draft recommendations for addressing any impediments to exploration.

These working group reports were incorporated into the final report of the Strategic Leaders Group which was presented to the Acting Minister for Industry, Tourism and Resources, the Hon. Joe Hockey, on 25 July 2003. The report contained twelve recommendations aimed at increasing mineral exploration in Australia. The report is being used as the basis of discussions within government, with the aim of developing an Action Agenda for Cabinet consideration later in 2003. The Action Agenda will include identified actions for industry and government in addressing the mineral exploration issue.
On 24 May 2002, the Minister for Industry, Tourism and Resources, the Hon. Ian Macfarlane, referred an inquiry to the House of Representatives Standing Committee on Industry and Resources to investigate any impediments to increasing investment in mineral and petroleum exploration in Australia (see www.aph.gov.au for the terms of reference). The inquiry — often referred to as the Prosser Inquiry after the chair, the Hon. Geoff Prosser — is expected to table its report in Parliament in September 2003. The government will respond to the inquiry in parallel with its consideration of the Mineral Exploration Action Agenda.
impact of public geological surveys in Australia

It is highly likely that the substantial public investment in geoscientific information over time has had a significant impact on the location and level of private mineral exploration activity and discoveries in Australia.

In this chapter, key stages in the mineral exploration process are outlined and the empirical evidence on the impact of public geological surveys in Australia is briefly reviewed. To date, the empirical evidence has primarily been collected and assessed by geologists or geoscientists within the public geological survey organisations or university system. Although the evidence is mainly qualitative, it provides a useful guide to the linkages between public and private mineral exploration activity in Australia, in terms of both timing and location.

The mineral supply process

Mineral exploration is the process of finding and assessing the characteristics of mineral deposits:

- **Public mineral exploration expenditure** is an investment in knowledge about the geology of the continent at a regional scale — regional geoscience maps and other information are provided to induce investment by the private sector in mineral exploration; and

- **Private mineral exploration expenditure** is an investment in knowledge about the location, size and quality of mineral deposits — private explorers invest in mineral exploration based on an assessment of the expected profitability of such an activity, taking into account the various geological, economic and sovereign risks.

Discovery, and evaluation, of mineral deposits is required before minesite development and mineral production and processing may proceed. Each stage in the process is influenced, to varying degrees, by the geological, economic and policy environment. Key stages in mineral exploration, production and processing are indicated in figure B.

The public geological survey organisations are, in a general sense, the outcome of a policy decision. However, the range of decisions made within those organisations that relate to the timing and location of individual geological surveys are influenced by various geological, economic and policy factors (see chapter 5 for a discussion of some of these issues).
Key stages in mineral exploration, production and processing

- Geological, economic and policy setting
  - Australia's mineral resources
  - World mineral market conditions
  - Government policies

- Public geological surveys
  - Maintenance of information on current land/tenement status
  - Regional mapping to obtain basic geoscientific information
  - Maintenance of historical exploration information
  - Increase the accessibility of the information through modern digital systems - with internet based access
  - Dissemination of the information to the private sector

- Generative stage
  - Selection of areas for more detailed exploration

- Primary exploration stage
  - Exploration of lease areas for mineral occurrences

- Evaluation stage
  - Evaluation of economic viability of mineral occurrences

- Development stage
  - Construction of minesite, processing and related infrastructure

- Production/processing stage
  - Mineral extraction, processing and transport to markets

- Minesite rehabilitation stage
  - Minesite rehabilitation following economic depletion of lease areas
In general terms, the key objectives in public geological survey organisations are:

- to maintain information on current land/tenement status;
- to provide new regional geoscientific data, most recently using modern technologies particularly airborne geophysics, in areas of high mineral potential to support target area selection for exploration by private exploration and mining companies;
- to maintain a database of historical exploration reports and data;
- to increase the accessibility of the information, most recently by developing modern digital systems; and
- to disseminate the information to exploration and mining companies.

A range of geological, economic and policy factors influences the decisions of private exploration and mining companies relating to exploration, development, production, processing and the environment. The assessment of risk adjusted profitability is influenced by expectations and risks relating to, for example, mineral prospectivity, mineral prices, technologies, input costs more generally, land access and government policies. A range of government policies are relevant to industry, from sector specific policies such as mineral taxation and approval processes to broader policy processes such as microeconomic reform and macroeconomic policy settings.

Private mineral exploration is a high risk process that comprises a number of sequential information gathering steps. A decision to initiate an exploration program or proceed to the next stage of an existing program implies that the expected benefits of obtaining additional information outweigh the expected costs, taking into account the risks. When a company is assessing whether exploration should take place, an implicit or explicit assessment is made of the probability of discovering an economic mineral deposit. The public provision of basic geoscientific information provides private companies with more reliable information than would otherwise be available in making this assessment, and hence reduces private exploration costs and risks. The absence of basic geoscientific information therefore increases the uncertainty associated with discovery and is a disincentive to private exploration investment.

Private mineral exploration (broadly defined to include exploration and evaluation) comprises many sequential decisions, but it is useful to identify three key stages — the generative, primary exploration and evaluation stages:

- in the generative stage of private mineral exploration, companies identify areas that are considered to be prospective for target minerals using public geoscientific information and supplementary private reconnaissance work;
- in the primary exploration stage, areas that have been identified as prospective for target minerals are acquired and tested in much greater detail by private explorers, the aim being to identify new zones of mineralisation that prove to be economic to mine; and
- where primary exploration activity has resulted in the discovery of a mineral deposit, the evaluation stage involves reserve delineation (to define more accurately the size, grade and physical characteristics of the mineral deposit), mine planning, metallurgical
testing, feasibility studies and predevelopment planning including financing and government approvals and an assessment of the least cost method of mining.

‘Success in the exploration stage comprises the discovery of new mineral occurrences and in the later stages of the exploration stage these are further evaluated, generally by way of a drilling program, which, if successful, leads to the discovery of an economic deposit and defines the size, grade and geometry of the deposit’ (Williams and Huleatt 1996, p. 54).

Where the evaluation stage indicates an economic project, the development stage involves construction and development of the minesite and related mineral processing facilities. The requirements of the development stage will also be influenced by the availability and cost of other infrastructure services such as energy, transport and water. Housing and other infrastructure associated with the labor force and their families is a further consideration.

In the production/processing stage, companies undertake mineral extraction, processing and marketing activities. Processing of minerals includes smelting, refining and chemical processes, which result in the production of a refined metal cathode, ingot or equivalent basic forms. Mineral processing at or close to the minesite reduces transport costs. As the purity of the metal increases with processing, it becomes relatively more cost effective to locate the final processing plants closer to other inputs such as electricity generators.

Minesite closure occurs with the economic depletion of mineral ore deposits from that location. Declining reserves at a particular minesite, however, may encourage further exploration around the existing deposit in order to extend the longevity of the mine and/or processing plant.

In the minesite rehabilitation stage, companies rehabilitate the minesite according to a strategy approved by government. This may require environmental restoration during as well as at the end of the mining operation depending mainly on the nature of the mining operation (Allen, Maurer and Fainstein 2001).

The mineral supply process is discussed further in several papers, including Gocht, Zantop and Eggert (1988), Mackenzie and Doggett (1992), Williams and Huleatt (1996), Guj and Blight (1999) and PMSEIC (2001).

**Australia’s mineral resources**

In a very broad sense, the aggregate impact of public and private investment in mineral exploration over time may be summarised by Australia’s identified mineral resources (see Geoscience Australia 2002a,b).

Mineral resource classification systems are typically based on some version of the McKelvey box (figure C). The classification system includes both geological and economic assessments. The geological assessment takes into account information on quantity (tonnage) and chemical composition (grade), while the economic assessment takes into account information on economic factors such as commodity prices, costs and discount rates.
### Classification of mineral resources: the McKelvey box

<table>
<thead>
<tr>
<th>Geological classification of resources</th>
<th>Total mineral resources</th>
<th>Undiscovered resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic classification of resources</td>
<td></td>
<td></td>
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<tr>
<td>Economic resources</td>
<td></td>
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<tr>
<td>Subeconomic resources</td>
<td></td>
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<tr>
<td>Paramarginal</td>
<td></td>
<td></td>
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<tr>
<td>Submarginal</td>
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</tbody>
</table>

**Economic demonstrated resources (EDR)**

A resource defined to be a concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth’s crust that are either identified or presently undiscovered, and in such form that its economic extraction is presently or potentially (within a 20–25 year time frame) feasible.

- ** Identified resources** are specific bodies of mineral bearing material or petroleum accumulations, the location, quantity and quality of which are known from specific measurements or estimates from geological evidence. Identified resources may be either demonstrated — measured from detailed sampling on site, or indicated from less detailed sampling — or inferred from broad geological knowledge of the site with few, if any, samples or measurements.

- **Undiscovered resources** are unspecified accumulations that are expected to exist based on broad geological knowledge and theory. Undiscovered resources may be hypothetical which may be expected to exist in a known province under known geological conditions, or speculative which may occur in known geological conditions where no discoveries have previously been made.

Identified resources are further classified as economic or subeconomic. An economic resource implies that, at the time of determination, profitable extraction or production under defined investment assumptions has been established, analytically demonstrated or assumed with reasonable certainty. Subeconomic resources are resources that are less likely to be profitable to extract. Subeconomic resources may be paramarginal which almost satisfies the criteria for economic, or submarginal that would require, for example, a substantially higher commodity price or some major cost reducing advance in technology to render them economic.

- **Economic demonstrated resources** (EDR) are specific bodies of mineral bearing material or petroleum accumulations where the location, quantity and quality are known from
specific measurements or estimates from geological evidence and where production is assessed to be profitable with reasonable certainty.

The objective in the public geological surveys is not to discover or identify mineral deposits directly — that is, public geological surveys are not intended to shift resource assessments (at least in principle) from the undiscovered category in figure C to the discovered or identified category. Rather, public geological surveys aim to increase the probability of successful private exploration programs by providing regional geoscientific information that allows those companies to more effectively select, for more detailed exploration, areas within the undiscovered mineral resource category (or outside this category should new geological models be tested).

In Australia, identified (or discovered) resources are assessed for mineral resources other than petroleum (Geoscience Australia 2002a). Both identified and undiscovered resource assessments are conducted for petroleum. Undiscovered petroleum resource estimates in 2000 and 2001 have been taken from assessments undertaken by the United States Geological Survey (USGS) (Geoscience Australia 2001, 2002b). Prior to 2000, Geoscience Australia produced undiscovered petroleum resource estimates based on their AUSTPLAY model. (The AUSTPLAY model is still used for the production forecasts published by Geoscience Australia.)

### Economic demonstrated resources (EDR) and production for selected resources, Australia, 2001

<table>
<thead>
<tr>
<th></th>
<th>Australia in world EDR</th>
<th>Australia in world production</th>
<th>Australia’s EDR to production ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rank Share</td>
<td>Rank Share</td>
<td>1980</td>
</tr>
<tr>
<td>Gold</td>
<td>3 10</td>
<td>3 11</td>
<td>20 18</td>
</tr>
<tr>
<td>Base metals and nickel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>3 7</td>
<td>4 6</td>
<td>23 28</td>
</tr>
<tr>
<td>Lead</td>
<td>1 28</td>
<td>1 24</td>
<td>40 23</td>
</tr>
<tr>
<td>Zinc</td>
<td>1 18</td>
<td>2 17</td>
<td>46 23</td>
</tr>
<tr>
<td>Nickel</td>
<td>1 37</td>
<td>2 17</td>
<td>29 107</td>
</tr>
<tr>
<td>Coal and uranium b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black coal</td>
<td>6 5</td>
<td>4 7</td>
<td>327 149</td>
</tr>
<tr>
<td>Uranium c</td>
<td>1 30</td>
<td>2 27</td>
<td>76 81</td>
</tr>
<tr>
<td>Diamonds d</td>
<td>3 14</td>
<td>1 24</td>
<td>83 6</td>
</tr>
<tr>
<td>Mineral sands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ilmenite</td>
<td>1 32</td>
<td>1 22</td>
<td>31 100</td>
</tr>
<tr>
<td>Rutile</td>
<td>1 45</td>
<td>1 49</td>
<td>30 108</td>
</tr>
<tr>
<td>Zircon</td>
<td>1 42</td>
<td>1 37</td>
<td>26 75</td>
</tr>
<tr>
<td>Iron ore</td>
<td>4 9</td>
<td>3 17</td>
<td>156 68</td>
</tr>
</tbody>
</table>

**Notes:**  
- **a** EDR (end of calendar year data) as a share of production in the same calendar year.  
- **b** Based on financial year production (for example, 2000-01 instead of 2000).  
- **c** World EDR ranking is based on resources recoverable at less than US$80/kg U.  
- **d** World EDR rankings are based on industrial diamonds only, although Australia has one of the largest EDRs for gem / near gem diamonds. World production is based on natural gem and cheap gem diamonds in 2000. EDR/production for 1983, not 1980.  

**Sources:** Geoscience Australia (2002a); ABARE (2003b).
In the preparation of Australia’s identified mineral resource assessments, Geoscience Australia uses data reported for individual deposits by mining companies based on the Australasian code for reporting mineral resources and ore reserves, commonly referred to as the JORC code (JORC 1999; see also www.jorc.org). The JORC code sets out minimum standards, recommendations and guidelines for public reporting of exploration results, mineral resources and ore reserves. The code has been prepared by the Joint Ore Reserves Committee (JORC) which comprises the Australasian Institute of Mining and Metallurgy, the Australian Institute of Geoscientists and the Minerals Council of Australia.

Historical public and private mineral exploration have established that, by international standards, Australia is relatively abundant in mineral resources (Geoscience Australia 2002a). Reflecting this competitive advantage, Australia is a leading nation in the production and export of several mineral commodities (ABARE 2003b).

For example, in 2001, Australia ranked in the top six countries in terms of economic demonstrated resources (EDR) and production for gold, base metals (copper, lead, zinc), nickel, coal, uranium, diamonds, mineral sands, and iron ore (table 1).

Ongoing exploration expenditure is significant for each of these mineral resources. In 2001-02, these mineral resources accounted for 96 per cent of mineral exploration expenditure (excluding petroleum) in Australia.

The ratio of economic demonstrated resources to production, which provides a broad indication of stockholdings for each resource relative to production levels, is substantially lower for gold and base metals than for other major resources such as iron ore and coal (table 1). As a consequence, private exploration is particularly important for gold and base metals to provide discovery and production opportunities over the medium to longer term. In 2001-02, gold and base metals accounted for 64 per cent of mineral exploration expenditure (excluding petroleum) in Australia (including nickel, this share increases to 72 per cent).

More generally, significant private exploration occurs for a range of mineral resources as companies aim to increase the quality of the identified mineral deposits, or respond to perceived economic opportunities associated with major changes in prices and other factors (such as technological change) that substantially influence the assessed profitability of any new discoveries.

**Impact of regional mapping on private mineral exploration in Australia**

A relatively limited number of papers have examined the empirical evidence on the impact of public geological surveys on the timing and location of private mineral exploration activity in Australia. Some empirical evidence, mainly as reported in Williams and Huleatt (1996) who draw on a number of sources including most notably Woods (1988) and Day (1995), is presented in this section.

Direct discoveries of mineral ore deposits are not the objective in the public geological surveys. However, Williams and Huleatt (1996), based on Woods (1988), indicate that
geologists in Geoscience Australia (under the organisation’s former titles AGSO and BMR) have directly discovered several significant mineral deposits during the course of their geological mapping. These are all in the Northern Territory and include:

- the Peko copper–gold mine;
- the Woodcutters lead–zinc–silver mine;
- the Mt Bundey iron mine; and
- several small uranium mines in the South Alligator uranium field.

Geoscientific information provided by Geoscience Australia is also acknowledged to have contributed to several significant mineral discoveries made by private exploration and mining companies, including:

- Warrego, Northern Territory — a copper–gold–bismuth mine;
- Olympic Dam, South Australia — a world class copper–uranium–gold mine;
- Groote Eylandt, Northern Territory — a world ranking manganese mine;
- Kambalda area, Western Australia — several nickel mines;
- the north west Queensland phosphate province — the Duchess mine and other deposits;
- Greenvale, Queensland — a nickel-cobalt mine;
- the East Alligator uranium field, Northern Territory — the Ranger uranium mine and other world ranking uranium deposits;
- Thalanga, Queensland — a copper–lead–zinc–silver mine;
- Yeelirrie, Western Australia — a uranium deposit;
- McArthur River, Northern Territory — a world class lead–zinc mine;
- Century, Queensland — a world class zinc mine; and
- Gove, Northern Territory — a world class bauxite mine.

While discoveries associated with geoscientific information provided by Geoscience Australia is the focus of the assessments by Williams and Huleatt (1996), they indicate that work by state/territory geological surveys has also resulted in several important discoveries. One important example they cite is:

- Boddington, Western Australia — a major gold mine.

Notably, the release of new government aeromagnetic data in the early 1990s led to several major discoveries that contributed to the upturn in private mineral exploration expenditure in the mid-1990s (see figure A).

As reported in Williams and Huleatt (1996), Day (1995) examined the impact of regional geological mapping on private mineral exploration activity in various geological provinces in Queensland. In three different time periods — 1971–75, 1981–85 and 1986–91 — the release of geoscientific information by the Geological Survey of Queensland (GSQ) and/or
Geoscience Australia coincided with an upturn in private exploration activity as measured by the number of mineral exploration permits taken out by industry.

Day (1995) noted that some of the regions were already the focus of some exploration activity prior to the commencement of the new regional mapping. However, in each case private exploration increased when new public mapping commenced. Day (1995) concluded:

- exploration activity increases in areas whenever new public mapping commences;
- exploration activity over time remains high in these areas; and
- exploration increases occur over time in the areas considered prospective for minerals.

More recently, Scott, Dimitrakopoulos and Brown (2002) examined the impact of regional data upgrade programs in the Geological Survey of Queensland.

Williams and Huleatt (1996) also provided examples from South Australia and Tasmania relating to the positive impact of public geoscientific information on private mineral exploration activity in the early 1990s. The Broken Hill Exploration Initiative and Discovery 2000 are discussed briefly in Lambert (1999).

Updated information on regional mapping programs is available from the relevant federal, state and territory geological survey organisations (see chapter 2 for website details).
economic efficiency of public geological surveys

The role of government in the early high risk stage of mineral exploration is well recognised by economists (see, for example, Gaffney 1967; Herfindahl 1974; Peterson 1977; Smith and Ulph 1982). Public geological surveys have an important role in reducing both the costs and risks of private mineral exploration.

An alternative arrangement whereby the government also undertakes detailed mineral exploration and auctions the mineral production rights from successful exploration activity to private companies has also been debated in the literature. This approach is argued to have the advantage of avoiding the complexities associated with assigning mineral exploration rights to private companies and overcoming the information externalities issue, but the economic efficiency of detailed mineral exploration is likely to be substantially reduced (see, for example, Crommelin and Thompson 1977; Emerson and Lloyd 1983, p. 235; Garnaut and Clunies Ross 1983, p. 86). This latter approach is mainly relevant to developing nations where sovereign risk is particularly high, resulting in low private mineral exploration activity (even in relatively prospective areas). Current best practice advocated by the World Bank limits the role of governments to providing a transparent regulatory regime and basic geoscientific information to encourage investment in mineral exploration and development by the private sector.

The main objective in this chapter is to examine the economic rationale for public geological surveys. Background information on the relevant economic principles is provided in this chapter, underpinning much of the discussion in the next chapter on key issues relating to public geological surveys.

Economic rationale for public geological surveys

Several factors are relevant when examining the economic rationale for public geological surveys including:

- the public good attributes of basic geoscientific information;
- the high risks associated particularly with the early stage of mineral exploration, and risk averse private investors;
- economies of scale in regional mapping and information dissemination;
- potential land access difficulties for private explorers; and
- the presence of information externalities.
The following discussion is focused on the role of public geological surveys in mineral exploration. However, as noted in chapter 2, there are potentially other important applications of these survey techniques, most notably with respect to dryland salinity and other natural resource management, and infrastructure and civil engineering issues. Industry externalities and policy goals such as regional economic development are discussed briefly in chapter 5.

Public good attributes of public geological surveys

As indicated in Davies et al. (1999), basic geoscientific information is an example of a non-rival but exclusive good.

Pure public goods are characterised by the problem of jointness in use and may also be nonexcludable (see, for example, Boadway and Wildasin 1984):

- joint consumption or use of a good, also known as nonrivalness in consumption or use by several individuals (consumers or firms respectively), occurs when one individual’s consumption or use of the public good does not detract from the benefits simultaneously accruing to other individuals from the same good; and

- nonexcludability in consumption or use occurs when it may not be possible, or is at least very costly, to exclude particular individuals from the consumption or use of the existing output of the public good.

The jointness in use property of public goods applies to goods simultaneously consumed or used by individuals in a given population at the local, regional, national or international level. A public good that applies specifically to the production side of the economy may be referred to as a public intermediate good.

The properties of nonrivalness and nonexcludability in use imply there are difficulties with the efficiency of the market pricing mechanism. Nonexcludability implies that sellers cannot charge users a price since those users can consume the public good free of charge (the free rider problem).

In the case where the public good is excludable but nonrival, there are still difficulties with market pricing. The individuals who simultaneously consume or use the good generally derive different total and marginal benefits from the same output. For a given level of output, each individual could be charged a different price according to the marginal benefit that accrues to that individual. On efficiency grounds, individuals should not be excluded from using the public good even if exclusion is possible since, because of the jointness in use property, the marginal cost of allowing one more individual to use the public good is zero. As a consequence, any pricing mechanism that excludes individuals is inefficient.

The marginal costs (supply) and marginal benefits (demand) of a public good are illustrated in figure D. The public good is assumed to be basic geoscientific information provided by the public geological surveys (PGS). The supply curve, \( S_{PGS} \), is the marginal cost of providing basic geoscientific information through the public geological surveys. For simplicity, only the demand curve for a single user is included in figure D. The curve, \( D_{PGS,1} \),
**Supply of basic geoscientific information from the public geological surveys (PGS) in a simplified economic framework**

\[ S_{PGS} \] represents the demand curve for individual user 1 in the sense that it indicates the marginal benefits of the information to that user at various levels of provision — this is, the price the user would be willing to pay at different information output levels (if a price were actually charged). The aggregate demand curve, \( D_{PGS} \), is derived by summing the individual demand curves vertically.

The optimal level of basic geoscientific information, \( Q_{PGS} \), is determined by the intersection of the aggregate supply and demand curves, indicated by \( E_{PGS} \). At this point, the cost of providing an additional unit of information (marginal cost) equals the sum of the benefits of the additional unit of information to all users (marginal benefit). This is the optimal level since the marginal cost would exceed aggregate marginal benefits at higher levels of output and, conversely, the marginal cost would be less than the aggregate marginal benefits at lower levels of output.

In principle, if the individual demand curves could be estimated, the public good could be supplied at its optimal level and individual users charged according to benefit pricing, also referred to as the Lindahl equilibrium (or solution). Under a benefit pricing system, individuals would be charged a price for the public good equal to their marginal benefit or willingness to pay at the level actually provided.

In figure D, for example, user 1 would be charged a price equal to \( MB_{PGS,1} \) for information provision at \( Q_{PGS} \) — other users would be similarly charged according to their individual demand curves, which may vary from user 1’s demand curve. At the optimal level of provision, the sum of the individual benefit prices would equal marginal cost since \( MB_{PGS} \) is equal to marginal cost at \( Q_{PGS} \) and, by definition \( MB_{PGS} \) is equal to the sum of individual prices; that is:

\[
MB_{PGS} = \sum MB_{PGS,i}^*
\]
where $\sum_i$ is the sum over all users of the information ($i = 1, 2, ..., N$ assuming $N$ users).

Benefit pricing has practical limitations since the individual marginal benefit curves are not observable. If the government attempts to charge benefit prices, each individual has an incentive to understate the benefits to reduce the benefit price under the assumption that the total provision of information would not be altered by the actions of a single individual. However, if sufficient individuals adopted this behavior, the government’s estimate of aggregate demand for the information would be substantially reduced, resulting in a suboptimal level of information provision.

As noted above, even if individuals could be excluded from using the public good at a given level of information provision, it would be inefficient to do so since the cost of providing the good would be unaffected by allowing these individuals to use the good and benefits would be increased.

The role of the pricing mechanism for a public good differs from that of a private good. Pricing is an important allocative mechanism for private goods (for example, signaling changes in tastes and preferences of consumers and changing profit opportunities for producers), but this is not the case for public goods. The role of prices for public goods is to finance the provision of the public good and to determine how these costs will be shared between users (if users can be identified).

There is a very substantial and growing economics literature on the free rider problem and revelation of preferences, particularly with respect to environmental issues. It is beyond the scope of this study to examine recent developments in this area. However, it may be argued that these problems are less important for public intermediate goods since the provision of these goods may result in increased profits (or rents) of users, which are observable.

Basic geoscientific information is a public intermediate good that may be used simultaneously by a group of private explorers in assessing areas for more detailed mineral exploration. From an industry perspective, the benefits of this information should accrue to private companies in the form of increased economic profit or rent. Mineral royalty arrangements may therefore serve the dual purpose of collecting a return to the community for the use of the resource as well as financing the public geological surveys (and other public economic and scientific information programs).

While each private explorer potentially benefits from access to basic geoscientific information, exclusive property rights are assigned by the government to individual companies for detailed mineral exploration and, if successful, typically also for mineral production. The extent to which industry economic rent increases as a consequence of the public geological surveys therefore also depends critically on the efficiency of the mechanisms adopted by government to assign mineral exploration rights. In establishing these mechanisms, and considering the economic arguments for public geological surveys more broadly, it is important for governments to recognise that the international market for mineral exploration funds is highly competitive.
Other economic arguments for public geological surveys

Without the basic geoscientific information provided through public geological surveys, private explorers would obtain the information through alternative means — by directly undertaking exploration individually or in a joint venture, or by purchasing the information from another company. Consistent with the argument given above, it is not efficient for private companies to duplicate basic exploration effort in any given area and it is highly likely that any private pricing of the information would also be inefficient.

In addition to the public good attributes of basic geoscientific information, there are several other factors that influence the economics of public geological surveys. While each of these factors alone may not provide sufficient rationale for the public provision of basic geoscientific information, they are important considerations in assessing the role of public geological surveys.

Risk and attitudes toward risk

Mineral exploration is risky, and the behaviour of private explorers (as with other private agents) is generally assumed to be characterised by risk aversion. By providing basic geoscientific information, public geological surveys reduce the risks to private explorers by reducing exploration costs and increasing the probability of successful exploration in the selected areas. The reduction in risk would encourage the entry of smaller private explorers who would otherwise have more limited opportunities for adopting exploration risk management strategies (risk spreading and diversification through, for example, participation in joint ventures) compared with larger private explorers.

Efficient resource allocation relies on risk neutral behavior which requires appropriate insurance markets. However, insurance markets will not be provided because of moral hazard problems. Irrespective, mineral exploration is only one of many risky economic activities. While the level of risk inherent in mineral exploration may not in itself justify government intervention, the presence of risk does amplify the benefits of the basic geoscientific information provided through the public geological surveys. This issue is discussed further in the next section.

Economies of scale and land access issues

By undertaking geological surveys at the regional level, public geological surveys are well placed to take advantage of any economies of scale. If there are economies of scale in regional mapping and information dissemination programs, as is often argued, public geological surveys encourage the participation of a larger number of smaller private explorers than would otherwise be the case.

Without public geological surveys, if a single large private explorer planned to undertake the mapping program in a particular region to take advantage of any economies of scale, issues relating to land access and the deductibility of such expenditures under company income tax arrangements would need to be addressed — inefficiencies in pricing would remain an issue. (The related issue whereby public geological surveys may choose to contract regional mapping initiatives to the private sector is not considered in this paper.)
Information externalities

Private explorers benefit directly from mineral discoveries by typically gaining production rights over the ore deposit, but may also provide or signal important information to other explorers — these indirect industry benefits from discoveries are referred to as positive externalities or spillover effects. There are two important sources of information externalities in mineral exploration:

- a significant new discovery in a greenfields area provides information to other private explorers about the location of the deposit that may signal the prospectivity of the area to other private explorers; and
- a discovery of a new type of deposit provides information to other private explorers about the geology of the deposit — this may lead to the enhancement of geological models that may increase the probability, or reduce the costs, of discovering further deposits.

To the extent that there are positive externalities from mineral exploration in greenfields areas, there may be some tendency for private explorers to wait to explore new areas until another private explorer has made a discovery in the region — that is, private explorers may attempt to free ride on the investment in exploration in greenfields areas made by other companies. The provision of basic geoscientific information from a public geological survey in a particular region increases the likelihood that one or more private explorers will commence exploration in that region.

Similarly, there may be some tendency for private explorers to wait to undertake exploration based on new geological models in order to free ride on the investment that other private explorers may make on testing new ideas. Public geological surveys provide basic geoscientific information that is likely to reduce the cost of testing new geological models and hence increases the likelihood that such exploration will occur.

Public geological surveys, risk and attitudes toward risk

Private investors - profitability assessments of risky projects and attitudes toward risk

A simplified decision tree for risky mineral or petroleum projects is presented in figure E. At each stage of the decision tree — exploration (comprising area selection, detailed exploration and evaluation of discoveries), development, production/processing and mine-site rehabilitation/abandonment — there is a range of geological, economic and policy risks. These risks tend to be reduced as the investor gains information and proceeds through each stage for any given project.

In the exploration stage, it is assumed that an investor selects and ranks alternative sites in order of preference based on the investor’s assessment of the profitability of each project before proceeding with detailed exploration and evaluation of discoveries. The profitability of a project is assumed to be assessed on the basis of a probability distribution of net present values of possible outcomes. The net present value is the discounted net cash flow over the expected duration of the project. In these assessments, net present value is assumed to be discounted at the risk free interest rate.
An investor’s attitude toward risk taking may be characterised as:

- **risk neutral**, whereby the investor is indifferent to the risks that an outcome may be either worse or better than expected;
- **risk averse**, whereby the investor is relatively more concerned about the risk of unexpected losses than the risk of unexpected gains; or
- **risk taking**, whereby the investor values the risk of unexpected gains more highly than the risk of unexpected losses.

Although it is possible for investors to be risk taking (or risk preferring), this is typically not regarded as a realistic representation of the behavior of companies in practice.

If investors are risk neutral, the profitability assessment for a project is based on its expected net present value (that is, the probability weighted sum of net present values). The project is assessed to be:

- economic or profitable if the expected net present value is positive (where the economic rent is given by the expected net present value);
- marginal if the expected net present value is zero (where capital is expected to earn only normal profits at the risk free interest rate); and
- uneconomic if the expected net present value is negative (where the capital would be expected to earn a higher rate of return in an alternative investment).

If investors are risk averse, the profitability assessment for a project is based on its certainty equivalent value (that is, the value at which the investor would be indifferent between the risky project and a project with a certain return). The certainty equivalent value \((CEV)\) is equal to the expected net present value \((ENPV)\) less a risk premium \((RP)\):

\[
CEV = ENPV - RP
\]

The risk premium represents the compensation that risk averse firms require for incurring risk. For risk averse investors, the project is assessed to be:
economic if the certainty equivalent value is positive (where the economic rent is now given by the certainty equivalent value);

- marginal if the certainty equivalent value is zero (where capital is expected to earn normal profits including a risk premium); and

- uneconomic if the certainty equivalent value is negative (where the capital would be expected to earn a higher risk adjusted rate of return in an alternative investment).

In practice, investors use a range of criteria to assess the viability of projects, including the internal rate of return, the payback period (number of years in which the investment expenditures are recouped) and the net present value based on a risk adjusted discount rate. However, the net present value approach based on a risk free interest rate is a useful economic framework that highlights the economic implications of public geological surveys, particularly under conditions of risk aversion.

**Risk averse investors**

The implications of risk aversion on the investor’s profitability assessment of a risky project is indicated in figure F. The probability distributions of two profitability measures — the net present value and the corresponding internal rate of return — are given in figure F, panels a and b respectively. The internal rate of return is the discount rate that would result in a zero net present value, noting that the figure is indicative only since the internal rate of return may not be well defined in some circumstances (see, for example, Brealey and Myers 1991 for a discussion of these issues). However, this comparison is useful since government and industry participants are more familiar with the internal rate of return concept.

The investor is assumed to assess the risks inherent in the project and identifies the required risk premium and certainty equivalent value of the project. The risk premium in present value terms (figure F, panel a) has a corresponding risk premium in the internal rate of return (figure F, panel b). The profitability of the project is based on the certainty equivalent value. The expected internal rate of return ($E_{irr}$) is the probability weighted sum of the internal rates of return for a given risky project (assumed to be well defined), and has three components:

\[ E_{irr} = i^f + i^p + i^{rent} \]

where $i^f$ is the risk free interest rate, $i^p$ is the risk premium in the rate of return and $i^{rent}$ is the rate of return associated with the economic rent or supernormal profits (certainty equivalent value) of the project. The normal rate of return on the project is equal to $i^f+i^p$ and the excess rate of return is given by $i^{rent}$.

In the economics literature, expected utility theory is a commonly used approach to estimate the certainty equivalent value of a risky project (see, for example, Hinchy, Fisher and Wallace 1989; Hogan 2003). According to expected utility theory, the investor assesses the utility of the risky options and prefers the project with the highest expected utility. The investor’s utility curve is assumed to be a function of wealth (or income) and is illustrated in figure G under various attitudes toward risk.
As Hinchy, Fisher and Wallace (1989) note, the mean–variance framework is also often used in practice. In this approach, projects are ranked on the basis of the mean and variance of the probability distributions. The variance is a measure of the risk of the project. A probability distribution is strictly preferred to an alternative if it has a larger mean and smaller variance. In other cases, the investor needs to trade off the mean and variance by using some other approach.

The mean and variance refer to the first and second moments of the probability distribution. Other theories refer to the role of skewness (the third moment of the probability distribution) in ranking projects. Skewness provides a measure of the lack of symmetry or the extent

---

**Probability distributions of profitability measures of a risky project with risk averse investors - certainty equivalent approach**

### a. Net present value (NPV)

1. Economic rent
2. Probability
3. Risk premium
4. NPV probability distribution

### b. Internal rate of return (irr)

1. Risk free interest rate
2. Risk premium in irr
3. Irr probability distribution

---

*Net present value, NPV, is discounted at the risk free interest rate. The internal rate of return is the constant discount rate that makes the corresponding NPV equal to zero. If the NPV is zero, the internal rate of return will equal the risk free interest rate assuming the risk free interest rate is constant over time. Note that in some circumstances the internal rate of return may not be well defined. See, for example, Brealey and Myers (1991) for a discussion of these issues.*
to which a probability distribution is positively or negatively skewed. The third moment will be positive if the distribution is positively skewed (as is likely to be the case in mineral or petroleum exploration). Kurtosis, given by the fourth moment, provides a measure of the extent to which a distribution is peaked or flat — this moment is not often used in practice.

Risky mineral exploration investment decisions

The impact of the basic geoscientific information provided by a public geological survey on the probability distribution of the net present value of a risky exploration project is indicated in figure H. For simplicity, the probability distribution of the project’s net present value before the public geological survey, given by \( f_0(NPV) \), is assumed to be able to be specified and is symmetric around the mean or expected net present value (which may be positive, zero or negative).

The public geological survey is assumed to provide private explorers with basic geoscientific information that enables them to update or revise the probability distribution of the net present value of the risky project. The variance of the updated probability distribution is assumed to be reduced, consistent with acquiring more information through the public geological survey.

For simplicity, the updated probability distribution is also assumed to be symmetric. Three possible outcomes are illustrated in figure H:

- \( g_1(NPV) \) is the updated probability distribution with an increase in the expected net present value;
- \( g_2(NPV) \) is the updated probability distribution with no change in the expected net present value; and
- \( g_3(NPV) \) is the updated probability distribution with a fall in the expected net present value.
Probability distribution of the net present value (NPV) of a risky project before and after public geological surveys assuming risk neutral investors.

- **a. Higher expected net present value**

- **b. Unchanged expected net present value**

- **c. Lower expected net present value**

\( f_0(NPV) \) and \( g_1(NPV) \) represent the probability distributions before and after surveys, respectively.

Net present value is discounted at the risk free interest rate.
The variance of each updated probability distribution is assumed to be identical. These three examples may be broadly interpreted as the outcomes from three separate potential exploration lease areas (EL₁, EL₂ and EL₃) with identical probability distributions, f₀(NPV), before the public geological survey (PGS).

The impact of the public geological survey on the profitability assessments of private explorers, under both risk neutrality and risk aversion, is given in table 2.

- The profitability of EL₁ is increased by the PGS for both risk neutral and risk averse private explorers since the expected net present value is increased and the risk premium is reduced.
- The profitability of EL₂ is unchanged by the PGS for risk neutral private explorers, but increased by the PGS for risk averse private explorers since the expected net present value is unchanged but the risk premium is reduced.
- The profitability of EL₃ is reduced by the PGS for risk neutral private explorers, but the impact for risk averse private explorers is uncertain based on the available information since both the expected net present value and risk premium are reduced. The private explorer would need to assess the cost of a lower expected net present value against the benefit of reduced risk.

Before the public geological survey, both risk neutral and risk averse private explorers are indifferent between the three exploration lease areas. After the public geological survey is

2 Impact of public geological survey (PGS) on profitability assessments in three exploration lease (EL) areas

<table>
<thead>
<tr>
<th>Comparisons</th>
<th>Risk neutral investor</th>
<th>Risk averse investor</th>
</tr>
</thead>
<tbody>
<tr>
<td>g₁(NPV) and f₀(NPV)</td>
<td>ENPV₁ &gt; ENPV₀</td>
<td>ENPV₁ &gt; ENPV₀</td>
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<tr>
<td>Expected net present value</td>
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<tr>
<td>Risk premium</td>
<td>RP₁ = RP₀ = 0</td>
<td>RP₁ &lt; RP₀</td>
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<tr>
<td>Certainty equivalent value</td>
<td>–</td>
<td>CEV₁ &gt; CEV₀</td>
</tr>
<tr>
<td>Impact on assessment</td>
<td>EL₁ more profitable after PGS</td>
<td>EL₁ more profitable after PGS</td>
</tr>
<tr>
<td>g₂(NPV) and f₀(NPV)</td>
<td>ENPV₂ = ENPV₀</td>
<td>ENPV₂ = ENPV₀</td>
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<tr>
<td>Expected net present value</td>
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<td>Impact on assessment</td>
<td>EL₂ profitability same after PGS</td>
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<tr>
<td>g₃(NPV) and f₀(NPV)</td>
<td>ENPV₃ &lt; ENPV₀</td>
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<td>Impact on assessment</td>
<td>EL₃ less profitable after PGS</td>
<td>Need more information</td>
</tr>
</tbody>
</table>

a Corresponds to probability distributions in figure H. Note that CEV = ENPV – RP. See text for details.
conducted and information disseminated, both risk neutral and risk averse private explorers rank the three areas such that $EL_1$ is preferred to $EL_2$ which is preferred to $EL_3$.

In practice, without basic geoscientific information, it may be difficult for private explorers to identify either the probability distribution of the mineral resource (or resources) or the probability distribution of the net present value in potential exploration lease areas. Any such probability distribution is also unlikely to be symmetric, but typically would be skewed to the right (such that there is a low probability of relatively larger ore deposits and corresponding relatively larger net present values). In addition, a private explorer may assess jointly a number of exploration lease areas to spread exploration risks across potential lease areas (or adopt other risk management strategies).

While the examples in figure H and table 2 are highly stylised, they do serve to illustrate key effects of public geological surveys. Public geological surveys provide private explorers with basic geoscientific information across all potential exploration lease areas in a region that enables each private explorer to make more informed decisions in profitability assessments, ranking potential exploration lease areas and finally selecting areas for more detailed exploration.

**Public geological surveys, economic rent and industry mineral supply**

**Economic rent and industry mineral supply**

In a competitive market, the economic rent from mineral resource exploration, development and extraction is the excess of revenue over costs where costs are defined to include a ‘normal’ rate of return on capital (that is, the minimum rate of return required to hold capital in the activity, including a risk premium where investors are risk averse) (Hinchy, Fisher and Wallace 1989).

The economic rent is typically regarded as approximating the return to the mineral resource and hence is often referred to as mineral or resource rent. Economic rent in a mineral resource industry may persist in the long run due to the quality or scarcity value of different ore deposits (or fossil fuel fields — for simplicity, references are made only to ore deposits but the concepts also apply to fossil fuel fields).

The quality rent is associated with the quality differential of ore deposits. The marginal cost of extraction tends to be lower for higher quality (more productive) deposits. For a given price, higher quality ore deposits earn a larger excess of revenue over costs than marginal ore deposits. The scarcity value of the resource reflects the opportunity cost of future production forgone when the resource is extracted in the current period. That is, if investors choose to extract the resource now, the value of doing so must be at least equal to the value of choosing to extract in some future period.

The concept of economic rent in mineral resources applies over the longer term, taking into account the following distinct economic activities:

- **production**: the cost of extracting resources from established mine sites (including abandonment costs);
Industry economic rent and mineral supply

new resource developments: the cost of producing ore from new resource developments based on mineral ore deposits that are known; and

exploration: the cost of finding new mineral ore deposits.

Long run industry mineral supply and economic rent are illustrated in figure I where price is assumed to be determined on world markets at $P_W$. The curve $S_1S_1'$ is the industry supply or long run marginal cost curve — this curve represents the total cost of resource production, including capital and exploration costs. Industry output is given by $Q_1$ and economic rent is the area where price exceeds long run marginal cost, given by the area $S_1P_WE_1$.

Implications of public geological surveys

Without public geological surveys, the industry supply or long run marginal cost curve would be higher than would otherwise be the case, reflecting the higher mineral exploration costs and risks borne by private explorers.

The implications of the public geological surveys for economic rent and long run mineral supply are illustrated in figure J. The curve $S_0S_0'$ is the industry supply curve without public geological surveys. At the world price $P_W$, industry output is $Q_0$ and economic rent is given by the area $S_0P_WE_0$.

The key effects of the public geological surveys at the industry level are therefore to reduce long run industry marginal costs (which includes an allowance for a risk premium), to increase industry output from $Q_0$ to $Q_1$, and to increase economic rent from the area $S_0P_WE_0$ to the area $S_1P_WE_1$.

It should be emphasised that figure J is a simplified framework that ignores the mechanism used to finance the public geological surveys. In broad terms, the public geological surveys...
may be considered to be cost effective if the cost of the surveys does not exceed the benefits, as measured by the gain in economic rent. The optimal provision of a public good was discussed earlier in this chapter. It was also noted that, since the effect of the public geological surveys is to increase industry economic rent, mineral royalty arrangements may be regarded as serving the dual purpose of collecting a return to the community for the use of the resource as well as financing the public geological surveys (and other public economic and scientific information programs). Issues relating to the financing of public geological surveys are discussed in the next chapter.
key economic issues relating to public geological surveys

Australia is a leading nation in the production and export of several mineral resources, due at least in part to the public geological surveys conducted by the federal, state and territory governments over the past several decades. Basic geoscientific information is a public intermediate good that reduces the costs and risks of private mineral exploration, and directly increases industry economic rent. Mineral royalty arrangements therefore serve the dual purpose of collecting a return to the community for the use of the resource and financing the public geological surveys (and other public economic and scientific information programs).

Quantifying the economic impact of public geological surveys is difficult since it requires an assessment of the expected net increase in industry economic rent. Obtaining feedback from industry users on the expected benefits of public geoscientific information provision provides some guide to location and technology choices in public geological surveys.

The objective in this chapter is to discuss some key economic issues relating to the efficient conduct of the public geological surveys. Issues include assessing the public geological surveys, financing the surveys, and location and technology choices (allowing for broader policy goals of regional and remote economic development).

Assessing public geological surveys

The public good attributes of the basic geoscientific information provided by the public geological surveys were discussed in the previous chapter. It was noted that basic geoscientific information is an example of a public intermediate good characterised by jointness in use (nonrival) but where users may be excluded through, for example, the imposition of specific cost recovery charges (excludability). Nonrival goods are most efficiently provided by a single seller.

The property of nonrivalness, even with excludability in use, implies there are difficulties with the efficiency of the market pricing mechanism. The private explorers who simultaneously use the information generally derive different total and marginal benefits from the same output. For a given level of public information provision, each private explorer could be charged a different price according to the marginal benefit that accrues to that individual. On efficiency grounds, private explorers should not be excluded from using the public good even if exclusion is possible since, owing to the jointness in use property, the marginal
cost of allowing one more individual to use the public good is zero. As a consequence, any pricing mechanism that excludes individuals is inefficient.

Together with any reconnaissance and related work in the generative stage of the mineral exploration process, public geoscientific information is used by private explorers to select areas for more detailed exploration under the conditions of an exploration lease. It is at the point where an exploration lease is allocated to a private company that the public geoscientific information for the specific location is not of direct use to other companies, at least for the duration of the lease.

If the company’s exploration is successful and a production lease is acquired, the public geoscientific data relating to this area may still be of interest to other explorers to the extent that there is information content about geological models that is relevant to other exploration activity. If the company’s exploration is unsuccessful and the lease is relinquished, the geoscientific information gained through the more detailed exploration process is collected, maintained and disseminated by the geological survey agencies. This information is nonrival until a new exploration lease is acquired over the site.

The public provision of geoscientific information directly reduces the costs to the industry since duplication of basic exploration effort is avoided. The public geological surveys are also well placed to take advantage of any economies of scale associated with regional mapping initiatives and information dissemination programs. In addition, there are likely to be some cost efficiencies in organisations such as Geoscience Australia that intensively use advanced technologies and highly skilled labor for a range of related activities — that is, there may be significant economies of scope within the public geological surveys. Geoscientific mapping is relevant to a range of land use planning and management decisions. Public investment in geoscience technologies and human capital over time is likely to have reduced the costs of recent nonmineral applications such as land management (salinity issues) and agriculture (soil mapping). Geoscience Australia, for example, also undertakes geoscience for a range of other applications, including seismic monitoring and risk assessments for earthquakes, landslide risk assessments and community risk studies (see www.ga.gov.au).

The benefits of providing basic geoscientific information through public geological surveys are also amplified because of the risky nature of mineral exploration.

That is, the public provision of geoscientific information has implications for both the costs and risks of private mineral exploration.

- Public geoscientific information allows private explorers access to information about the regional geological framework at lower cost than would otherwise be the case.

- Public geoscientific information reduces the geological risks involved in private sector decisions on which areas to target for more detailed exploration.

To the extent that private mineral exploration expenditure is increased as a consequence of the public geological surveys, information externalities have the potential to further encourage exploration by, for example, signaling the prospectivity of new regions.
Overall, the basic geoscientific information provided by public geological surveys results in increased private mineral exploration activity, which is likely to flow on to higher levels of mineral production, processing and exports, and increased industry economic rent.

An assessment of the optimal provision and pricing of public geoscientific information is beyond the scope of this study. However, surveying industry users is an approach that may be used to provide governments with a guide to the expected industry benefits of public geoscientific information provision (see the discussion in chapter 4).

In broad terms, public geological surveys would be considered to be cost effective if the benefits over time of the geoscientific information exceed the costs over time associated with the provision of this information.

Given the theoretical arguments and available empirical evidence, it is likely that the public geological surveys have been cost effective over time in Australia. The discussion in the remainder of this chapter, however, is relevant to this issue. Anecdotal evidence suggests that public geological surveys have widespread support within industry and are an important source of Australia’s competitive advantage in mining and mineral processing activities (see also Industry Commission 1991).

**Financing public geological surveys**

As indicated above, from an industry perspective, the benefits of public geoscientific information provision should accrue to private companies in the form of increased profit or economic rent. It should be noted that part of the economic rent may be diverted through, for example, resource taxation, land access negotiations and wage bargaining. Resource taxation or mineral royalty arrangements aim to capture some part of the industry economic rent — the payments received by governments under these arrangements represent a return to the community for the private use of the resource as well as a means of financing the activities of public geological surveys that directly benefit the minerals and petroleum industries.

An important issue with this interpretation of mineral royalty arrangements is that Geoscience Australia provides specialist input to regional mapping initiatives in the states and territories (see chapter 2). There are substantial cost efficiencies in the provision of specialist services at the national level to minerals related activity, although mineral royalties (excluding uranium and offshore petroleum) are collected by state and territory governments. Difficulties in addressing these jurisdictional issues, however, should not impede the efficient conduct of the activities of public geological survey organisations in Australia.

It may be assumed that the costs of Geoscience Australia associated with the efficient provision of basic geoscientific information for use in private mineral exploration are covered through adjustment to the general financing arrangements between the federal and state/territory governments (although this is unlikely to be done in any formal sense).

Based on PMSEIC (2001), the mineral exploration budgets of the public geological surveys in 1999-2000 is reported to have been around $75 million (see chapter 2). To provide some context, this compares with total mineral royalty payments to Australian governments of
$0.9 billion (excluding petroleum) and $2.4 billion (including petroleum) in 1999-2000 (table 3).

All jurisdictions receive significant mineral royalty payments, although revenue to South Australia, the Northern Territory and Tasmania is substantially below that for other jurisdictions (table 4). It should be noted, however, that the Australian government’s royalty payments from offshore petroleum production have been incorporated into the jurisdiction adjacent to the activity.

Any assessment of the efficiency or cost effectiveness of public geological surveys should take into account any distortions caused by the mechanisms used to finance those activities.

A range of mineral royalty or resource taxation arrangements are adopted in practice and are either output based or profit based systems:

- **specific royalty**: the payment to government is a constant amount per physical unit of production;
- **ad valorem royalty**: the payment to government is a constant percentage of the value of production;
- **excise**: a variation of the ad valorem royalty whereby the payment to government is an increasing percentage of the value of production; and
- **resource rent royalty or tax**: the payment to government is a constant percentage of the project’s net cash flow in each year of the project life where exploration and development costs are accumulated at a threshold rate and offset against future revenues.

Output based royalties generally apply to mining projects in the states and territories. There is considerable variation in the ad valorem and specific royalty rates levied both between states and territories, and between mineral resources. For example, the coal industry is subject to a specific royalty of $1.70 a tonne for underground mining and $2.20 a tonne for open-cut mining in New South Wales, and an ad valorem royalty of 7 per cent in Queensland. Some form of profit based royalty applies in a relatively small number of cases such as the Argyle Diamond mine project (combined ad valorem / profit system).

With the exception of the North West Shelf permit area, the petroleum resource rent tax (PRRT) currently applies to all oil and gas projects in offshore areas which are under the control of the Australian government. Projects in the North West Shelf permit area are subject to ad valorem royalty and excise arrangements.
In general terms, the administrative and compliance costs of a mineral royalty system increase with the amount of information required for its implementation. As a consequence, profit based royalties tend to be more costly to administer than output based royalties.

The additional administrative and compliance costs of a profit based royalty need to be assessed against the benefits of any efficiency gain. Efficiency gains from a profit based royalty arise when some resource projects become profitable under the system that would have been unprofitable under an output based royalty. Further, mine life may be longer under a profit based royalty than under an output based royalty. This is because the latter takes a constant share of revenue or output, rather than profit, during a period when unit costs are typically rising thus narrowing profit margins and causing the mining operation to become uneconomic sooner than would otherwise be the case.

The efficiency of resource taxation arrangements are examined in, for example, Hinchy, Fisher and Wallace (1989), Hogan and Thorpe (1990) and Hogan (2003) (see also the references contained in those studies). The extent to which industry economic rent increases as a consequence of the public geological surveys is also influenced by the efficiency of the mechanisms adopted by government to assign mineral exploration rights.

Discussion of industry levies and financing public information programs through general tax revenue is provided in Curran and Podbury (1994). Cost recovery by government agencies is also discussed in Productivity Commission (2001).

### Location and technology choices in public geological surveys

#### Private mineral exploration in production and other lease areas
Exploration activity may be usefully categorised by the level of exploration and mining activity that has previously occurred in the location:

- an area where there is current or past mining of a particular resource is referred to as a **brownfield area**;
- an area where there are no current mining operations or known mineral resources is referred to as a **greenfield area**; and
- **grassroots exploration** techniques are often referred to by industry and are usually taken to be those used early in an exploration program for new economic deposits, including the generative and primary stages.

#### Mineral royalties paid to Australian governments, by state and territory, 1999-2000

<table>
<thead>
<tr>
<th>Level</th>
<th>Share</th>
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<tbody>
<tr>
<td></td>
<td>$m</td>
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<tr>
<td>New South Wales</td>
<td>182.3</td>
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*For metal ore mining, coal mining, and oil and gas extraction. Source: ABS (2001).*

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*For metal ore mining, coal mining, and oil and gas extraction. Source: ABS (2001).*
A major objective in public geological surveys is to prioritise regional geological mapping programs according to areas of relatively high mineral potential, with some emphasis given to those locations that have previously been unexplored or underexplored (that is, greenfield areas).

Mineral exploration in greenfield areas tends to be higher risk than in brownfield areas since less information is available about the geology of the location. Lack of knowledge may imply that there is a relatively low probability of discovering a large ore deposit. However, exploration in greenfield areas increases the probability of discovering a new mineral province in Australia (with the consequent positive information spillover or externality effects).

Over the past two decades, there has been an increased emphasis on private mineral exploration in production lease areas, an indicator of exploration in brownfield areas (figure K). ABS data on exploration expenditure includes all expenditure by private companies during the exploratory and evaluation stages in Australia (see ABS 2003 for details). A production lease is an area on which mine site development is under way or where mineral production is already occurring. Other areas outside the production lease includes areas under an exploration or retention licence or permit, and non-licenced areas being assessed for exploration for example through airborne surveys.

The share of private mineral exploration expenditure conducted on production lease areas has increased from an average of 11 per cent between 1979-80 and 1989-90 to 23 per cent between 1990-91 and 2001-02.

This shift reflects, to some extent, increasing land access difficulties, mainly relating to environmental and native title issues. Delayed, or forgone, access to land postpones or reduces the opportunities for private explorers to acquire knowledge about Australia’s mineral resources base. There are potentially both direct and indirect costs from mineral exploration that is delayed, reduced or forgone.

Indicators of private mineral exploration activity in greenfield areas in Western Australia are provided in Bowler (2002).
Selecting locations for regional mapping programs

The discussion in chapter 3 on the timing of public geological surveys and private exploration activity in Australia has not been comprehensive. However, there are a number of observations about the linkages between public geological surveys and private exploration activity that are of interest.

- The choice of region by public geological survey agencies may be influenced by developments in the location of private exploration activity. That is, public geological survey agencies take into account updated information on private exploration activity in relatively unexplored or underexplored areas.

- The announcement of a region selected for public geological mapping appears to have some information content by signaling to private explorers that public geological survey agencies have assessed this area to be relatively prospective for minerals.

- The release of basic geoscientific data encourages private mineral exploration activity by directly providing information to private explorers. Each private explorer must make a decision about selecting potential areas for more detailed exploration with the knowledge that there is no longer an option to explore a given area once a competitor acquires an exploration lease over that area.

Regional exploration initiatives, and more particularly subsequent mining activity, may have broader impacts on regional economies. Mining is important for many regional and remote economies (Hogan, Berry and Thorpe 1999; Productivity Commission 1999; Hogan and Byrne 2000; Garnaut, Connell, Lindsay and Rodriguez 2001). The role of mining in regional economies is particularly important given the Australian government’s policy initiative — the ‘Regional Australia Strategy’ — that was announced in 1998 and aims to achieve sustainable growth in regional Australia (Anderson and MacDonald 1999). Some key economic arguments relating to regional economic policies are discussed in appendix A.

For example, a major focus of the Exploration NSW activities is the far west of the state in the Broken Hill region. There has been substantial historical public and private investment in social and economic infrastructure in this region. With mining in Broken Hill expected to cease around 2006, the New South Wales government aims to encourage exploration and mining to support the regional economy.

It should therefore also be noted that part of the costs of public geological surveys, such as the Broken Hill Initiative, may be more associated with regional or remote economic support than with the optimal provision of basic geoscientific information for the mining sector, ignoring regional development issues.

Under the assumption of risk neutral decision making by governments, the location choices for regional mapping programs should be determined by, and ranked according to, the expected net economic benefits of each program. Implementation of a regional mapping program should proceed only if the expected net economic benefits of the program are non-negative.
Assume, for simplicity, that the benefits of the regional mapping program are fully captured by industry and the costs are the direct costs of the regional mapping program, including information dissemination. In this case, the expected net economic benefits of the regional mapping program is the expected increase in industry economic rent resulting from the public geological surveys — that is, the extent to which the certainty equivalent value of all projects in the region is expected to increase as a consequence of the regional mapping initiative — less the direct costs. The extent to which the increase in industry economic rent is captured by others (through, for example, resource taxation, land access negotiations and wage bargaining) should also be taken into account.

Other benefits and costs associated with any regional mapping program, if expected to be significant, may also be taken into account in the assessment. For example, governments may value the economic contribution that resource projects may make to communities in regional and remote areas of Australia. The geoscientific information from regional mapping programs may also be relevant to other applications such as land use management and infrastructure planning and development. Indirect costs from a regional mapping program may include, for example, environmental damage although regional mapping is a low environmental impact activity.

Technology adoption in public geological surveys

Technology adoption has an important impact on the economics of locating, extracting and processing mineral resources. For example, with many of Australia’s known high quality ore resources having already been developed, there has been a strong trend toward the mining of lower grade deposits. The introduction of new and cheaper extraction and processing technologies has meant that ore bodies of much lower grade (and size) can be treated for the economic recovery of minerals. New exploration technologies of particular interest are those that provide more information on subsurface geology.

In Australia, exploration is particularly important for gold and base metals where the level of economic demonstrated resources, relative to production, tends to be significantly lower than for other resources. With increased difficulties in accessing new areas for exploration in recent years mainly associated with native title and environmental issues, industry and government research agencies have responded in two important ways:

- first, by increasing mineral exploration in production lease areas (as indicated in figure K); and
- second, by developing new technologies — FALCON (BHP Billiton), TEMPEST (CRC AMET) and Glass Earth (CSIRO) — to enable explorers to assess mineral prospectivity at greater depths than was previously feasible.

More discoveries are expected in future with the development of these new geoscience technologies that provide more detailed data on subsurface geology (PMSEIC 2001).

FALCON was developed from US naval technology and BHP Billiton has adapted it for mineral exploration purposes. FALCON uses sensitive gravity based measurements to measure the density of rocks below the earth’s surface. (See www.falcon.bhpbilliton.com for further information.)
TEMPEST was developed by the Cooperative Research Centre for Australian Mineral Exploration Technology (CRC AMET), comprising Geoscience Australia, AMIRA International, CSIRO, Curtin University, the Geological Survey of Western Australia, Macquarie University and Fugro Airborne Systems. TEMPEST is an airborne system that uses electromagnetic pulses to generate small but measurable secondary magnetic fields in target bodies. (See www.crcamet.mg.edu.au for further information.)

The Glass Earth projects are designed to discover the next generation of economic mineral deposits by making the top kilometre of the Australian continent, and the processes operating within it, transparent. (See www.csiro.au for further information.)

Airborne surveys in general, allow for the systematic and uniform rapid acquisition of data and accelerate the identification or sterilisation of exploration areas, while minimising environmental impacts and access problems. The use of airborne surveys has a significant economic advantage over traditional ground based surveys in that they are more cost and time effective. These technologies can also be valuable environmental management tools — for example, TEMPEST is able to detect ground water salinity (PMSEIC 2001).

Consistent with the previous discussion, an assessment of investment in new exploration technologies to be used in the public geological surveys should be based on the expected net economic benefits of the investment. Breakeven analysis is an approach that may be used to assess the cost effectiveness of specific technology options where it is difficult to quantify the benefits and possibly some costs — the investment would be judged to be cost effective if the assessed net benefits over time are expected to exceed the identified costs of the investment.

Timing options for both regional mapping programs and technology adoption need to be accounted for in assessing the expected net economic benefits. The preferred timing of the introduction of any new exploration technology, for example, should be consistent with the highest expected net economic benefits. In the location and technology choices in the public geological surveys, surveying the key users of the information is an important mechanism to inform government of the expected benefits of specific options.
issues in regional economic policies

The location of exploration, mining and mineral processing activities is influenced by decision making in both the private and public sectors. Exploration, mining and mineral processing companies locate activities to maximise profit over time, taking into account the various costs and risks associated with different sites. Government policies may influence location decisions by altering the industry assessments of the economic viability of particular projects.

A key role of the public sector is to organise, directly or through private supply, efficient economic and social infrastructure (subject to budgetary and other constraints) to complement private sector economic activities and to ensure people have access to some reasonable level of infrastructure services. To facilitate private investment, governments also have an important role in maintaining a stable low inflation macroeconomic environment and providing a simple, stable and transparent institutional framework (to reduce the costs and risks of investment).

More generally, industry assistance provided by government may also influence the location of industry. The fundamental objective of industry assistance is to promote economic growth and employment. As discussed in some detail in Industry Commission (1996), several arguments are often put forward to provide selective assistance to industry.

- The presence of market failure whereby certain goods and services are not provided optimally through the normal workings of markets. Market failure may indicate a role for government action provided such action is cost effective and well targeted. Examples include public goods (such as defence), industries where the price does fully reflect net economic benefits and hence output is below the optimal level (such as research and development expenditure), and industries where there are substantial costs or difficulties in obtaining relevant market information.

- The presence of significant benefits through multiplier effects to the local and regional economies. Multipliers are summary measures of economic linkages and will only be positive if the investment represents a more efficient use of available resources. However, the net gains from alternative uses of government assistance also needs to be assessed.

- The presence of external benefits from agglomeration. Agglomeration is the observed tendency of firms in the same and closely related industries to cluster within a particular location to take advantage of, for example, increased supply of specialised labor and technological spillovers. Industry assistance has been argued in the context of targeting selected ‘seed’ firms to commence the process of agglomeration.
The presence of ‘lighthouse effects’ from a high profile investment project, particularly in depressed locations. A large high profile investment may assist in informing potential market participants and changing market sentiment about the costs and risks of investments in specific locations.

- Facilitate regional development, particularly in depressed regions, to reduce regional inequities and structural adjustment costs.

- The presence of intangible benefits from the staging of major events such as the Olympic and Commonwealth games.

- Competing against other state governments and overseas locations.

In practice, there are several issues in governments’ realising net gains from industry assistance (Industry Commission 1996).

- The extent to which interstate rivalry increases costs to taxpayers.

- Difficulties in acquiring information to assess the cost effectiveness of various policy options.

- The extent to which governments are risk averse and hence tend to select activities that have a significant probability of occurring in the absence of assistance.

- The risks of governments responding to short term political pressures.

- The risks of governments providing additional assistance to the project, even if the assistance was initially provided as a short term measure. This may be a particular risk for footloose industries.

- The extent to which assistance tends to favor well organised groups of firms or large firms.

- The extent to which firms incur costs to lobby governments for assistance, particularly if there are multiple assistance schemes.

- The risks of unfair competition to established firms in a region. (The concept of competitive neutrality was embodied in the national competition reform process to ensure individual firms are not specifically favored or penalised by government policies.)

Regional policies in Australia are described in Anderson and MacDonald (1999). The provision and pricing of infrastructure, industry assistance and regional development are discussed in, for example, Industry Commission (1993, 1996), OECD (1993) and Productivity Commission (1999).
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