Australian Government
Geoscience Australia

Australian Geological Provinces, Regions and Events

A standardised, national approach

Summary

Provinces are defined in terms of overlapping packages of rocks related by depositional or emplacement process, time and space (for example a sedimentary basin), and overprints resulting from various metamorphic or deformation events. These provinces and the events which formed them are recorded in Geoscience Australia corporate Oracle databases and linked with spatial data at a nominal 1:1millon scale in a GIS delivered via the WWW.

1. PROVINCES

1.1 THE GEOLOGICAL PROVINCES CONCEPT

Many publications and digital datasets have variously described the depositional, magmatic, structural, metamorphic, metallogenic, and/or geomorphic history of part or all of Australia. However, no standardised comprehensive compilation exists that can be used for continent-wide evaluation of the geological history and resource potential of Australia.

The Australian Geological Provinces Database seeks to provide a national register of the basic building blocks of Australian geology. As well as compiling attribute data for the provinces, polygon outlines of their geographic extent will be captured in the database. This standardised database format of province attributes will accommodate diverse regional classifications and allow consistent continent-wide correlations.

Geological provinces and their constituent units will initially be compiled at a nominal 1:1 million scale, although scope exists in the database to compile data at more and less detailed scales, with a hierarchy of super-provinces down to provinces, sub-provinces and domains.

The Provinces database will have close links with the Australian Stratigraphic Names Database and a new Events database. The Stratigraphic Names Database will provide the detailed attribute information for the stratigraphic subdivision of regional-scale sedimentary and igneous provinces. The Events database will store the geochronology and other characteristics of events which formed, shaped and overprinted geological provinces.

The compilation of Australian geological provinces is intended to be a co-operative venture between Geoscience Australia, the State and Territory geological surveys, and the research community. The Geoscience Australia database will provide a receptacle for province definitions from sources most appropriate for a region (such as State geological surveys). It will cater for reinterpretation of provinces, with alternatives and bibliographic sources clearly identified, providing a dynamic framework for geological interpretation of the continent.

To ensure the widest possible dissemination and use of the province data, Geoscience Australia will construct a WWW-based interface from which users can query, view and download both text attribute and spatial data from the Provinces and Events databases. The WWW interface will provide an easily accessible entry point for regional process analysis and resource evaluation for both domestic and international industry and research clients.

1.2 PROVINCE TYPES

Australian geological provinces are a standardised set of regional-scale crustal elements which reflect significant stages in its spatial and temporal evolution.

Provinces types fall into several groups:

1. Depositional or emplacement rock packages:
    - Sedimentary provinces (or basins)
    - Igneous provinces (intrusive and extrusive)

2. Overprinting provinces:
    - Structural provinces (overprinting regional deformation)

- Metamorphic provinces (regional and contact metamorphism)
- Metallogenic provinces
- Regolith-landform provinces

3. Composite rock packages:
   - Tectonic provinces

1.3 PROVINCE HIERARCHY

A hierarchical system of parent/child relationships for like province types is provided. The parent of a province entity is defined as the entity of the same province type and the next highest level in the province hierarchy.

Superprovince
↓
Province
↓
Subprovince
↓
Domain
↓
Subdomain
↓
Microdomain

Tectonic provinces may **contain** provinces of other types (see Section 1.4.7), but they may only be **parents** of other tectonic provinces. For instance, the Monaro Sedimentary Subprovince (Fig 1.1) is **contained within** the Lachlan Fold Belt (tectonic province), but its province **parent** is the Hume Sedimentary Province.

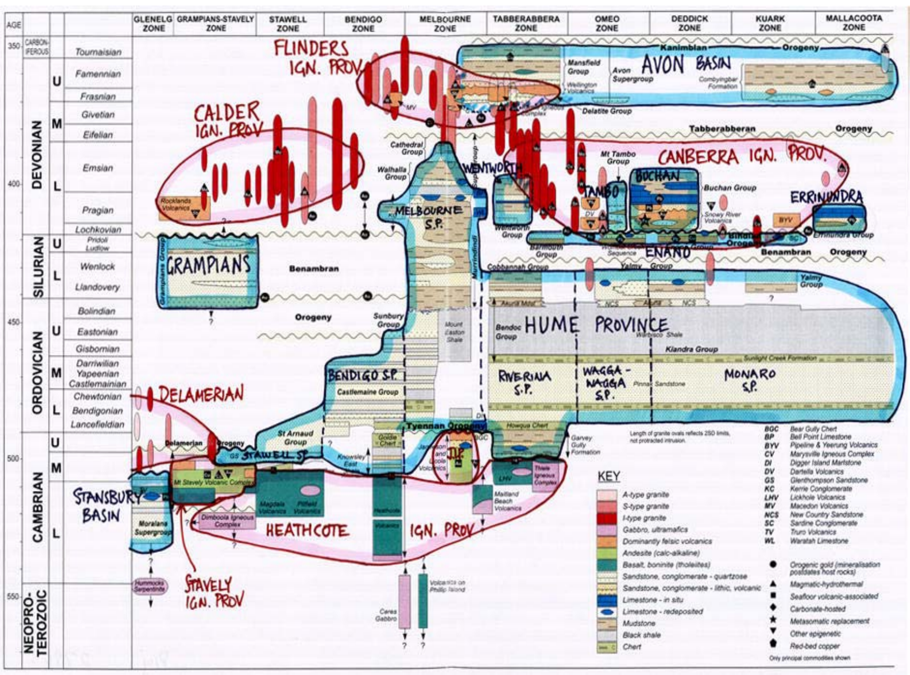

Figure 1.1 Time-space plot for the pre-Carboniferous geology of Victoria, with sedimentary and igneous provinces indicated (after VandenBerg et al., 2000).

1.4 PROVINCE TYPE DEFINITIONS

1.4.1 Sedimentary province

A **sedimentary province** (or **basin**) is an accumulation of sedimentary rocks, with or without volcanics, deposited or being deposited in a subsiding segment of the Earth's crust, whose lateral boundaries may be structural, depositional, erosional, or interpreted (in the sub-surface), and whose vertical boundary is a regionally extensive unconformity (Fig. 1.2). There is no restriction for the minimum or maximum extent of such a sediment fill in defining a sedimentary province (basin). Identification and nomenclature of the sediment fill is based on either stratigraphic nomenclature principles and/or sequence stratigraphic principles. Many sedimentary provinces are commonly referred in the literature to as "basins", and this widely accepted nomenclature should be retained where appropriate in the province description.

The basic element in the hierarchy of sedimentary provinces is the **basin** (≡ **province**). **Sub-basins** (**subprovinces**) may be designated, corresponding to major depocentres within a basin. A **super-basin** (**superprovince**) should be defined in the sense of an extensive collection of connected and genetically-related basins. The upper and lower surfaces of extensive sedimentary provinces (basins) are commonly diachronous. Such differences in geological history can usually be recognised by delineating sub-provinces (sub-basins). Other sub-provinces will reflect local difference in properties.

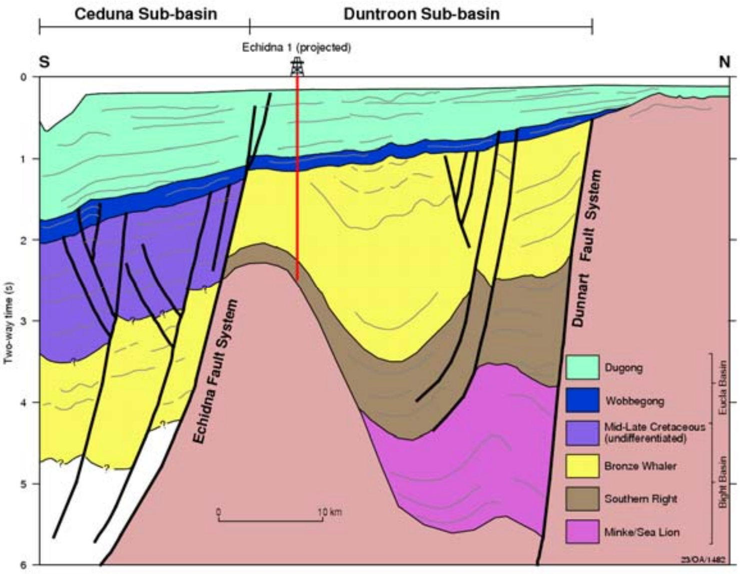

Figure 1.2 Cross section derived from a seismic reflection profile showing the Eucla Basin overlying Ceduna and Duntroon Sub-basins of the Bight Basin.

Basins should be defined on the basis of a distinct tectonic and depositional history, ie certain tectonic processes have produced a container in which certain sedimentary units were deposited. Constituents such as lithostratigraphic units (eg: group, formation, member) and lithochemical units (eg: suite and supersuite) will therefore generally be confined to a single basin. Exceptions may occur, however, where an extensive depositional unit has been arbitrarily subdivided and the parts named as basins, or where several established basins are eventually shown to be one (e.g. Eromanga, Surat, Clarence-Morton, Carpentaria, Laura and Papuan Basins). Where it is not possible to demonstrate depositional continuity between temporally similar sedimentary packages they should be assigned to separate basins.

Sedimentary provinces may contain some volcanic rocks which may also be part of an igneous province. For example, the volcanic component of an extensive subaerial igneous province may extend into a marine sedimentary basin that forms at the same time. In such cases the volcanic rocks are included in both provinces (Fig. 1.3).

1.4.2 Igneous province

Igneous provinces are temporally and geographically cohesive packages of igneous rocks. An igneous province may be compositionally heterogeneous (eg: consisting of several different igneous suites which are based on lithochemical characteristics), with both extrusive and intrusive components (eg: the Kennedy Igneous Province comprises all Permian and Carboniferous igneous rocks in North Queensland).

Extrusive igneous provinces (eg: Great Divide Igneous Province = Late Mesozoic to Cainozoic intraplate volcanic rocks in eastern Australia) are essentially unconformity-bound volcanic rock packages defined by stratigraphic nomenclature principles similar to sedimentary provinces. In some circumstances, discontinuous, relatively small volumes of strata within a definable sedimentary package, may be assigned solely to an extrusive igneous province.

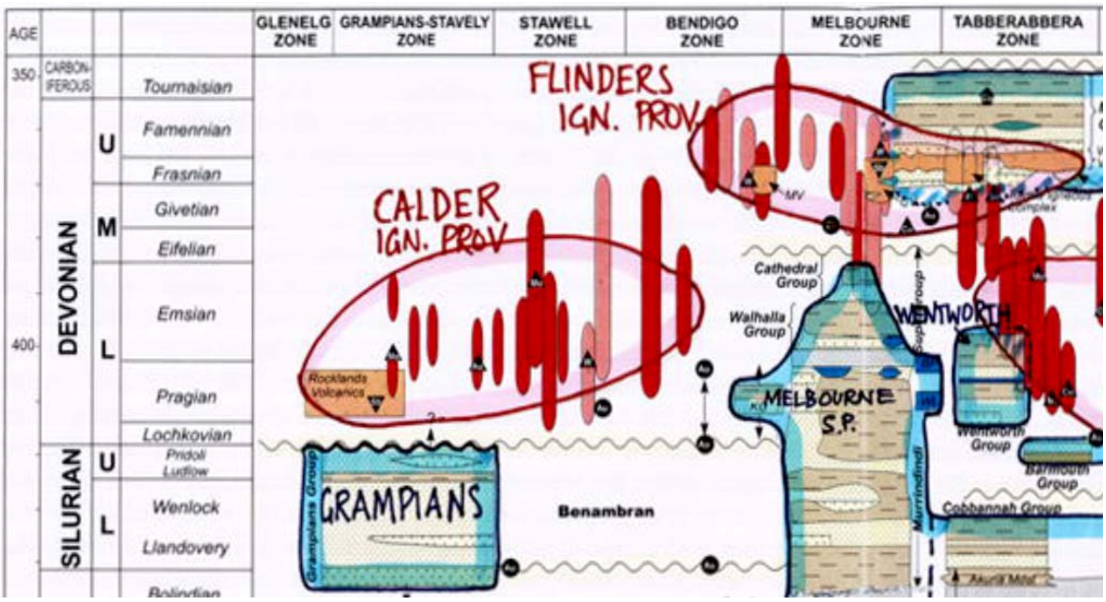

Figure 1.3 An example of combined intrusive/extrusive igneous provinces defined using the time-space plot of Victoria (VandenBerg et al, 2000) as a guide. Volcanics of the Flinders Igneous Province are also included in the overlapping sedimentary basin.

Some igneous provinces may have formed in a geologically brief period (thousands of years), others over a considerable period (10's or 100's of millions of years). Some will interfinger with sedimentary provinces and parts will also be included in those provinces. Some will be synchronous with metamorphic or structural provinces and linked with them through a common tectonic province.

To distinguish between spatially overlapping igneous provinces, a clear temporal separation is needed, preferably with an intervening sedimentary, metamorphic or structural province.

Alternatively there should be sufficient evidence, at the province scale, that the igneous provinces represent totally unrelated igneous groupings and/or events. Spatial patterns will also guide identification of separate but temporally adjacent or equivalent provinces.

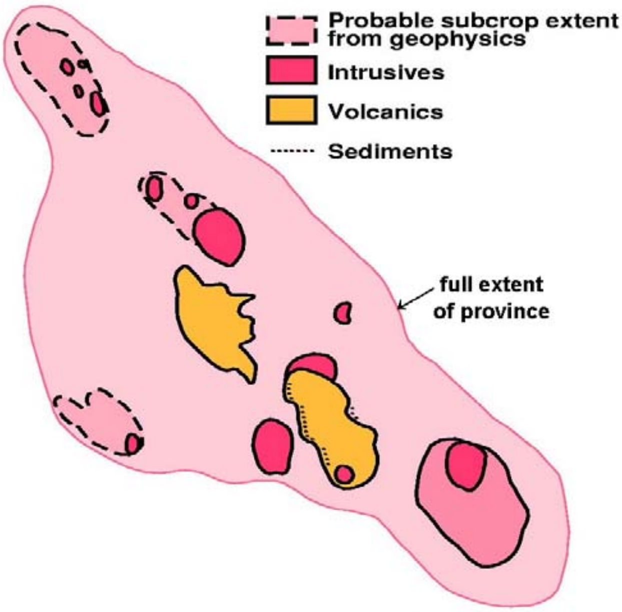

Fig 1.4 An example of intrusive and extrusive components of an igneous province which is concealed in part by younger cover rocks.

1.4.3 Structural province

Structural provinces are the spatial representation of the extent of deformation events. Structural provinces typically overprint igneous or sedimentary provinces, but may also overprint older structural and metamorphic provinces.

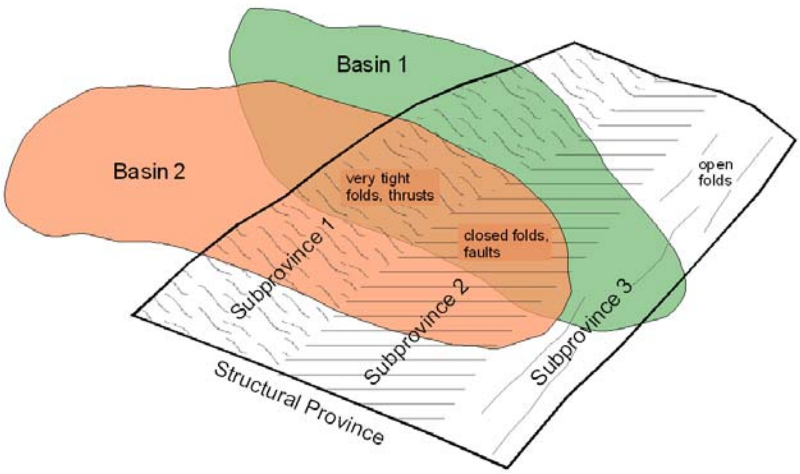

Figure 1.5 An example of a structural province which overprints two sedimentary basins and has three structural subprovinces based on variations in structural style and intensity.

They are three-dimensional shapes with specific age ranges and have event-related fabrics. As with the other province types, sub- and super-provinces may be defined to accommodate variations such as structural style (eg: folding, faulting, shearing), fabrics (eg: type and attitude), intensity (eg: open or tight folding), or age (eg: minor variations in the onset of a deformation event across a structural province) (Fig. 1.5).

A structural province may consist of the effects of one or more deformation events. This may occur if a coherent time period is marked by several events, perhaps marked by local unconformities, which are grouped together in a broader regional event (eg: local event variations in the Benambran Orogeny across the Lachlan Fold Belt in Victoria and New South Wales).

1.4.4 Metamorphic province

A metamorphic province represents the spatial extent of one or more metamorphic events. Metamorphic provinces typically overprint igneous or sedimentary provinces, but may also overprint older structural and metamorphic provinces.

In cases of complex and/or high grade metamorphic overprints (especially where combined with structural complexity), primary rock characteristics may be completely obscured, preventing identification of the sedimentary or igneous provinces that have been overprinted. In such cases, a metamorphic province may represent the rock package itself as well as the overprinting events. The ultimate goal, however, is to separate into separate provinces the formation of the substrate and the overprinting events.

Temporal continuity of metamorphic events should be established, together with coherent regional characteristics, to form a metamorphic province. Subprovinces may be distinguished, for instance, to delineate variations in metamorphic conditions from a regional metamorphic event.

1.4.5 Metallogenic province

A metallogenic province was defined by Bates & Jackson (1987) as an area characterised by a particular assemblage of mineral occurrences. However, in consistency with the principles outlined herein for other types of geological provinces, some degree of temporal grouping should also apply to a metallogenic province (cf. metallogenic epoch). Metallogenic provinces may include the mineralised parts of one or more mineral systems. Mineral systems represent a spatial and temporal continuum of elements ranging from sources of materials and energy to mineral deposits (or hydrocarbon accumulations) and the pathways connecting them. Diverse commodities and deposit styles may be linked within a single mineral system.

1.4.6 Regolith-landform province

No strict definition of regolith-landform provinces currently exits. A hierarchical system of definition of soil and regolith-landform units and regional regolith-landform provinces is being developed through cooperation of Australia's national and state soil and regolith mapping agencies.

1.4.7 Tectonic province

Groups of provinces linked by a common tectonic history are designated as tectonic provinces. Tectonic provinces may contain a collection of sedimentary, igneous, structural, metamorphic and metallogenic provinces (Fig. 1.6).

Published tectonic nomenclature is extensive, complex, mostly hierarchical, It includes:

- **spatial terms** such as:
  Shield, Platform, Block, Inlier
  Structural zone, domain
  Tectonic, orogenic and fold systems, belts, belt systems, and domains
  Mobile zone or belt;
  Cratonic, Neocratonic regions, systems and domains

- **event terms** such as:
  Evolutionary or Chelogenic interval
  Orogeny
  Orogenic episode
  Tectonic event, phase, pulse

- and **time-space terms** such as:
  Orogen, Craton
  Tectonostratigraphic elements, terranes (super- and sub-)
  Stratotectonic elements

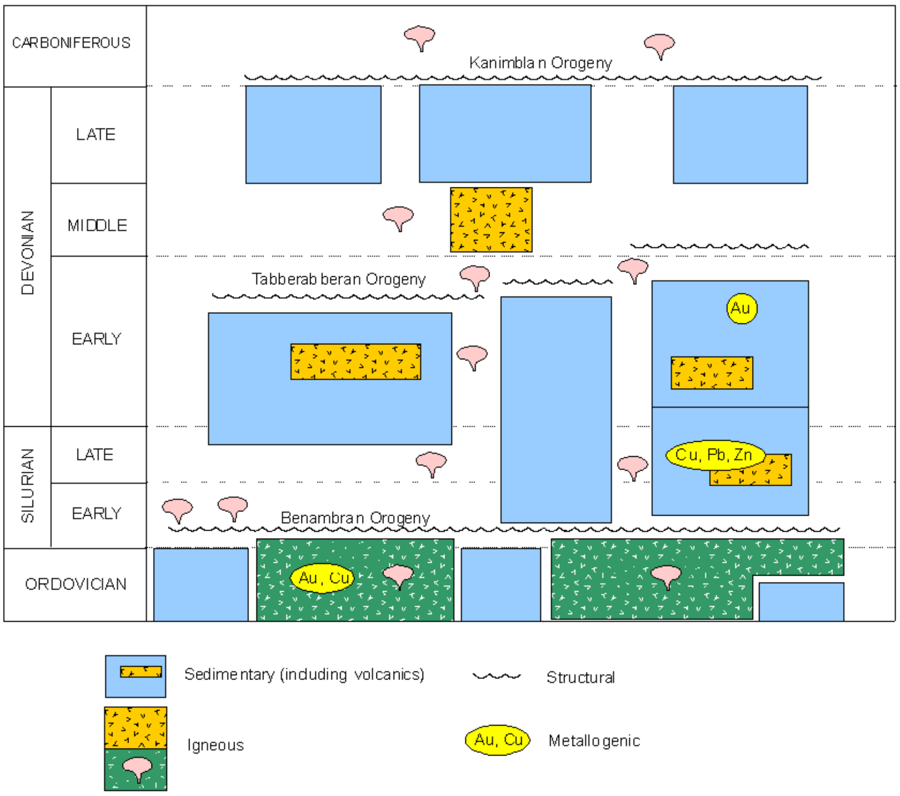

Figure 1.6 A timespace plot cartoon showing some of the component province types which make up the northern part of the Lachlan Fold Belt (a tectonic superprovince).

In some cases, previously published stratotectonic or structural elements/terranes/zones may be directly analogous to tectonic provinces used in the Geoscience Australia scheme. However, the boundaries and subdivision of tectonic or stratotectonic elements have often been defined on a mix of geological, geographical or other convenient grounds, mainly due to the restrictions of representing their extents on a two-dimensional map. The Geoscience Australia scheme recognises that tectonic provinces may overlap in time and space and boundaries are not limited by two-dimensional constraints.

The hierarchy of Geoscience Australia's tectonic provinces starts with tectonic superprovinces being defined as the largest tectonic elements which comprise the Australian continent. Broadly, these correspond to the cratons (blocks) and fold belts (orogens) which have accreted to form the Australian crust. For example:

superprovince	Yilgarn Craton	New England Fold Belt
province	Eastern Goldfields Province	Tamworth Zone
subprovince	Norseman-Wiluna Belt	Rouchel Block

Of all the province types, tectonic provinces typically involve the greatest degree of interpretation and thus definitions may be less universally accepted. In recognition of this, the Provinces database allows for multiple definitions of provinces, although only one will be the "GA preferred" definition (see Section 1.8), based on widest scientific acceptance and consistency within the national tectonic framework.

It is emphasised that the term "inlier" corresponds only to the exposed parts of many tectonic provinces, and as such describes a geological region (see Section 2). "Inlier" should not be used in naming tectonic provinces which commonly extend beneath younger cover rocks.

1.5 TECHNIQUES FOR PROVINCE DEFINITION

Provinces may be defined on the basis of both observed (measurable) attributes and interpreted attributes such as:

Observed	Interpreted
Rock types (composition, mineralogy, fabric)	Associations (eg: structural, tectonic)
Relationships and ages	Environments (eg: depositional, igneous, tectonic)
Distribution, dimensions, form	Palinspastic relationships (eg: stress fields)
Metamorphic conditions, alteration overprints	Causes of events (origins)
Geophysical characteristics	Processes
Mineral or petroleum resources	Extrapolations, predictions

Provinces are four-dimensional. They have an area and thickness, and represent a definable period of geological time. Provinces may be small or large, and their contents single- or multi-component, as a result of their mode of formation (eg: sedimentation or intrusion) or subsequent overprinting processes (eg: deformation).

Provinces may overlap in time and/or space, and their full extent beneath covering or overprinting provinces should be defined as accurately as practicable. Interpretation of potential field data, drilling and other such datasets may be necessary to define reasonable outer limits for many or most provinces.

Time-space plots (Fig. 1.1) and seismic reflection profiles (Fig 1.2), together with surface, bedrock and basement geology maps, provide the most direct and useful tools to define and delineate geological provinces. Usually, no one of these datasets will provide an unambiguous definition of a province.

1.6 PROVINCE ATTRIBUTES

Attribute data that can be stored within the Provinces database (Fig. 1.7) includes:

- Province name (and synonyms)
- Province type and subtype
- Minimum and maximum ages (biozone or absolute ages)
- Age dating methods (if any) and estimated error margins
- Parent/child hierarchy of related provinces
- Relationships to surrounding provinces (eg: overlying, underlying, interfingering, intrusive, overprinting relationships)
- Links to the Geological Events database
- Constituent lithostratigraphic and sequence stratigraphic units, linked through the Stratigraphic Names database
- An extended attribute list for individual province types, including:
  - tectonic environment/environment of deposition for sedimentary and igneous provinces
  - lithostratigraphic and sequence stratigraphic attributes for sedimentary provinces
  - lithochemical parameters (eg: redox state, I/S/A type) for igneous provinces
  - structural styles
  - metamorphic facies
  - resources
  - and many others
- Name of province interpreter and date of interpretation
- References to sources of information

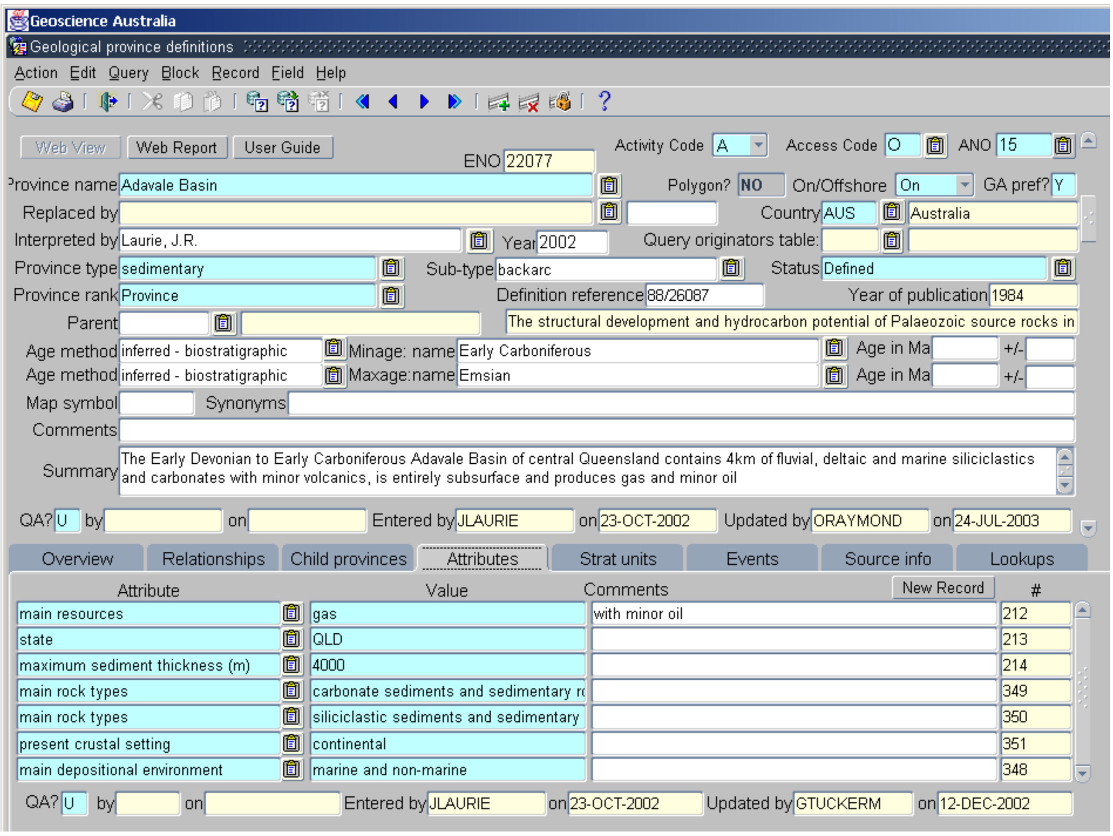

Figure 1.7 An example of a Provinces database entry.

1.7 PROVINCE EXTENT POLYGONS

As far as is practical, polygons defining the spatial extent of provinces should be based strictly on geological grounds. Geographical features such as coastlines, state boundaries, or boundaries of cartographic convenience should not be used for geological province boundaries.

The spatial extent of a province is represented by three polygon types (Fig. 1.8):

- Exposed extent (outcrop)
- Concealed extent (subcrop beneath insubstantial surficial cover)
- Maximum or full extent (inferred beneath substantial cover, commonly an overlying province)

The maximum extent polygon of a province has several features:

- It encloses all exposed and concealed parts of a province.
- It may often be a smoothed outline which encloses scattered outcrops of a province which are isolated by erosion, structural processes, or emplacement (eg: scattered igneous intrusions).
- It may enclose some other rocks which are included or surrounded by rocks of the province.
- It may extend beyond the limit of concealed constituents where, for example, geophysical or drilling data indicate deeper extensions of a province beyond its exposed and thinly concealed portions.

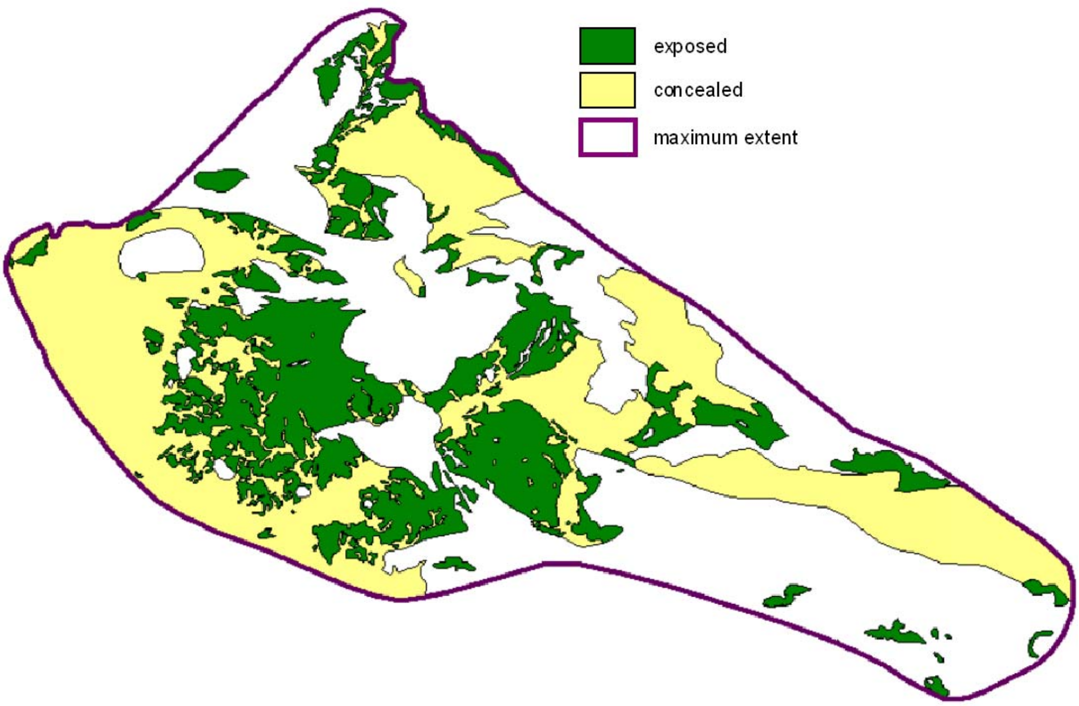

Figure 1.8 Exposed, concealed and maximum extents of the Burdekin Basin of north Queensland.

Where possible, the maximum extent of each province should be represented by a single polygon. However, if for example, parts of a sedimentary province are separated by later structures over relatively long distances, the maximum extent of the province may comprise more than one polygon (Fig 1.9).

Figure 1.9 Example of polygon types in a sedimentary province (basin). In this case, two parts of the basin are significantly separated by a fault, creating a two-part maximum extent polygon.

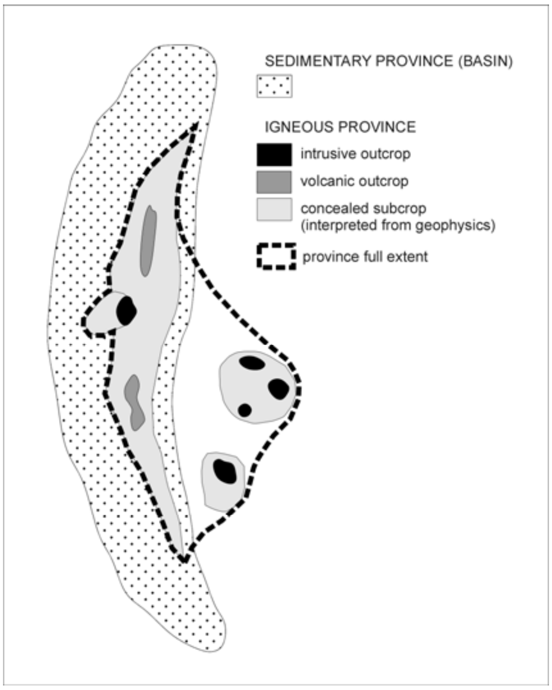

Figure 1.10 Example of polygons associated with a mixed intrusive/extrusive igneous province which intrudes and interfingers with a sedimentary province. The volcanics are included in both the igneous province and sedimentary province.

The maximum extent of a province is defined by a series of bounding segments, each segment representing a significant change in either the geological nature, positional accuracy, or interpretation confidence of the boundary. Confidence levels on segments of the maximum extent polygon boundary may range from definite to highly conjectural (Fig 1.11). Attributes for boundary segments are captured in the Provinces database.

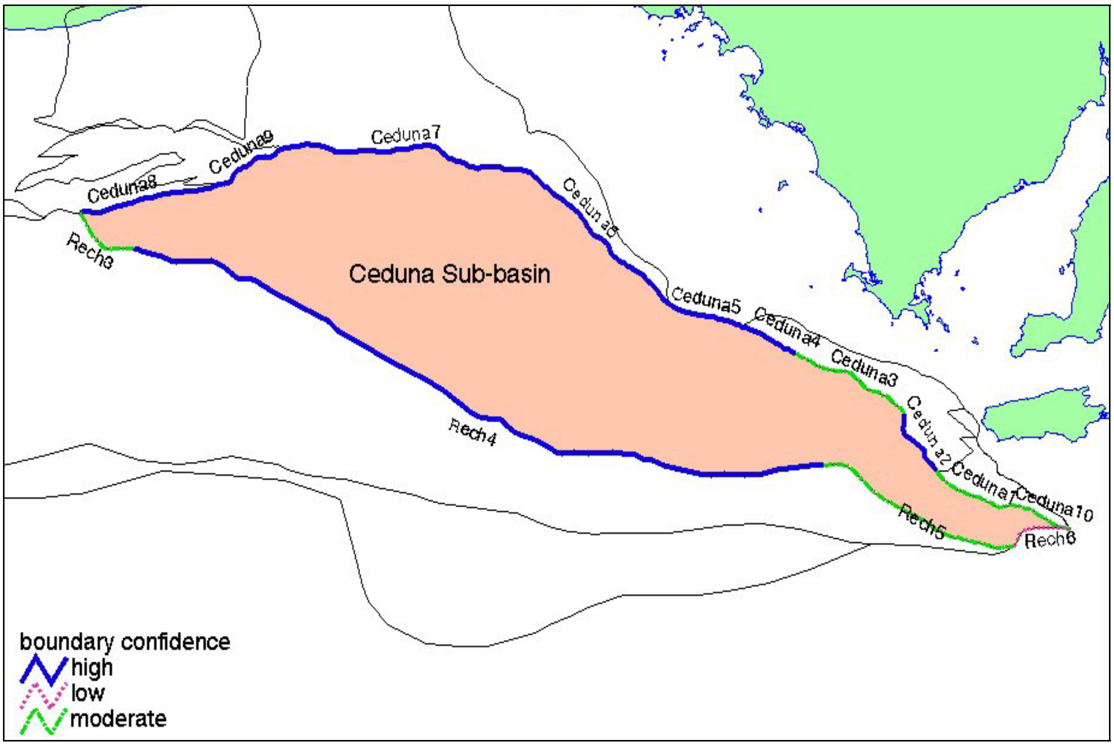

Figure 1.11 An example of interpretive confidence levels assigned to the boundaries of the Ceduna Sub-basin.

1.8 MULTIPLE PROVINCE DEFINITIONS AND "GA PREFERRED"

It is recognised that the definition of Australian geological provinces needs to accommodate a range of geological opinion and the evolution of interpretations with new techniques and data. This is particularly so with the more complex and interpretative province types such as tectonic provinces.

Province definitions which are superseded by new definitions in the light of new data are not deleted from the database. Instead, they are coded as “superseded” with a link to a new province (or provinces) description to allow users to view historical interpretations where necessary.

If researchers have different interpretations of a geological province, the database can accommodate multiple current definitions. However, to permit the construction of coherent national maps, one of the definitions must be designated as “GA preferred”. The “GA preferred” status is granted by consensus of an appropriately qualified and representative group of GA staff, with reference when appropriate to external experts, and only to province descriptions which meet minimum levels of attribution and have adequate spatial representation.

2. GEOLOGICAL REGIONS

Geoscience Australia maintains a distinct terminological separation between **provinces** and **regions**. Geological regions are two-dimensional areas with contrasting geological characteristics represented by the dominant outcropping geology. They are convenient geographic subdivisions of Australia from a geological perspective, but they do not facilitate regional correlation or analysis in so far as they focus mainly on the exposed geology. In a broad sense, a region may be thought of as the intersection of a three-dimensional province with the Earth's surface. Under Geoscience Australia's terminology, geological regions may be subdivided further into **terranes**.

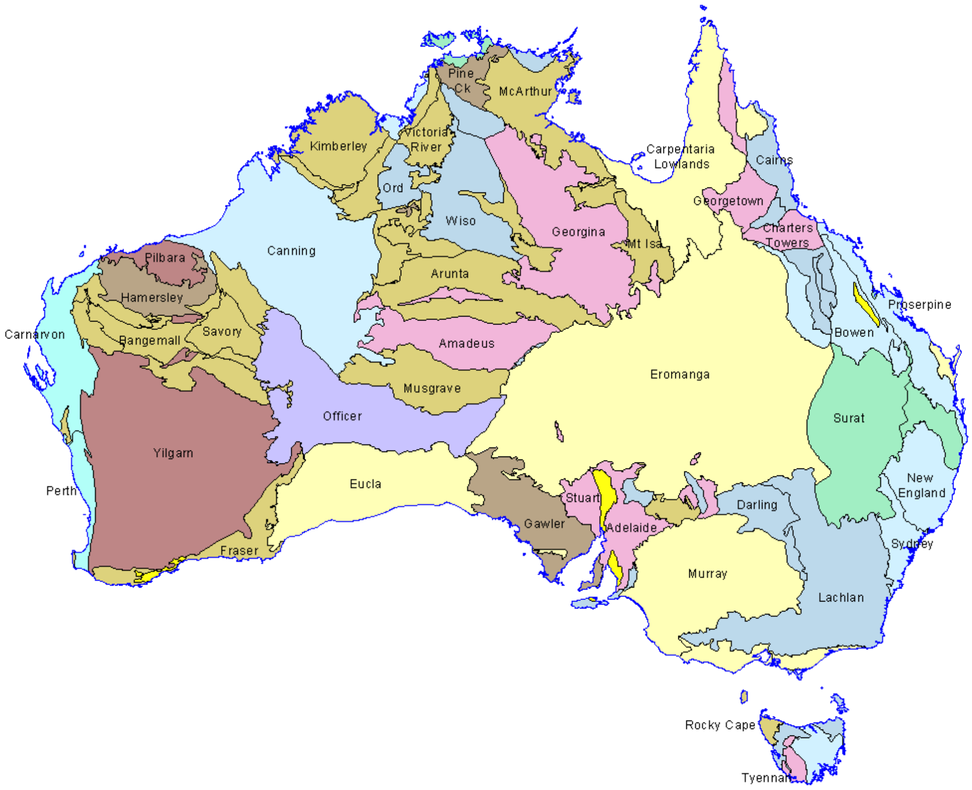

Figure 2.1 Australian geological regions (Blake & Kilgour, 1998; selected names shown). This dataset is available at http://www.ga.gov.au/rural/projects/20011023_32.jsp.

3. GEOLOGICAL EVENTS

Geological events mark the formation and evolution of geological provinces. A Geological Events database, linked to the Provinces database has been established as an adjunct to the documentation of geological provinces, but is currently largely unpopulated. Each event is named, defined and linked to provinces with supporting evidence.

Examples of event types to be documented in the Events Database include:

- Igneous (eg: intrusive, extrusive)
- Depositional (eg: transgression, regression)
- Deformation (eg: extension, compression, shear)

- Metamorphic (eg: regional, contact, burial)
- Tectonic (eg: major orogenic events which may comprise several deformation and/or metamorphic events)
- Metallogenic
- Fluid Flow
- Seismic
- Aquatic/marine/oceanic (eg: anoxic)
- Geomagnetic
- Geomorphic (eg: erosion/incision)
- Atmospheric (eg: climatic/glacial)
- Biospheric (eg: extinctions)
- Extraterrestrial (eg: impacts)

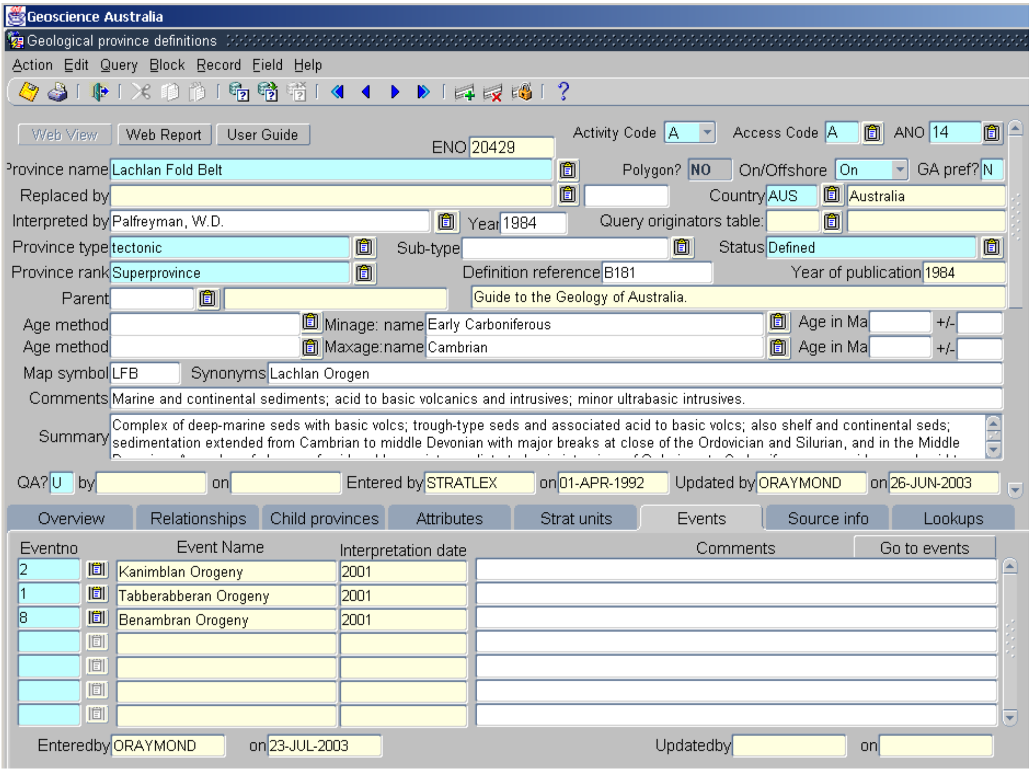

Figure 3.1   An example of tectonic events (eg: Kanimblan Orogeny) linked to a tectonic province (Lachlan Fold Belt) in the Provinces Database.

4. REFERENCES

Bates, R.L. and Jackson, J.A., 1987. Glossary of Geology (3rd Edition). American Geological Institute, Virginia.

Blake, D.H. and Kilgour, B., 1998. Geological Regions (National Geoscience Dataset). 1:5 million scale digital map dataset, Geoscience Australia, Canberra, Australia.

VandenBerg, A.H.M, Willman, C.E., Maher, S., Simons, B.A., Cayley, R.A., Taylor, D.H., Morand, V.J., Moore, D.H., and Radojkovic, A., 2000. The Tasman Fold Belt System in Victoria. Geological Survey of Victoria. Special Publication, 462pp.