Mountain Building at a Convergent Plate Tectonic Boundary: The Southern Adelaide Fold Belt

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Introduction

Mountain belts are zones of lithosphere thickening along the boundaries between colliding tectonic plates. Examples of modern mountain belts include the European Alps, Andes, Himalayas and the PNG Highlands. Mountain belts are characterised by rock deformation (i.e. folding and faulting), regional metamorphism, and igneous intrusions. When plate tectonic collision ceases mountain belts become incorporated into the stable continental lithosphere and are called fold belts. Ore deposits are formed by the circulation of mineral-bearing hydrothermal fluids. Such fluids are generated during mountain building by the heat associated with metamorphism and igneous activity.

The Adelaide Fold Belt (Figure 1) is an example of an ancient mountain belt that was active over a 24 million year period during the late Cambrian to earliest Ordovician Periods. The mountains subsequently eroded away and their remnants are now exposed in the Flinders Ranges, Mount Lofty Ranges, and Kangaroo Island. The southern part of the Adelaide Fold Belt, exposed in the Mount Lofty Ranges, provides an excellent case-study for mountain building because changes in rock deformation, metamorphism and igneous activity can be mapped between the outer fold belt and its inner core. Numerous mineral deposits have been found in the southern Adelaide Fold Belt and several of these have been mined.

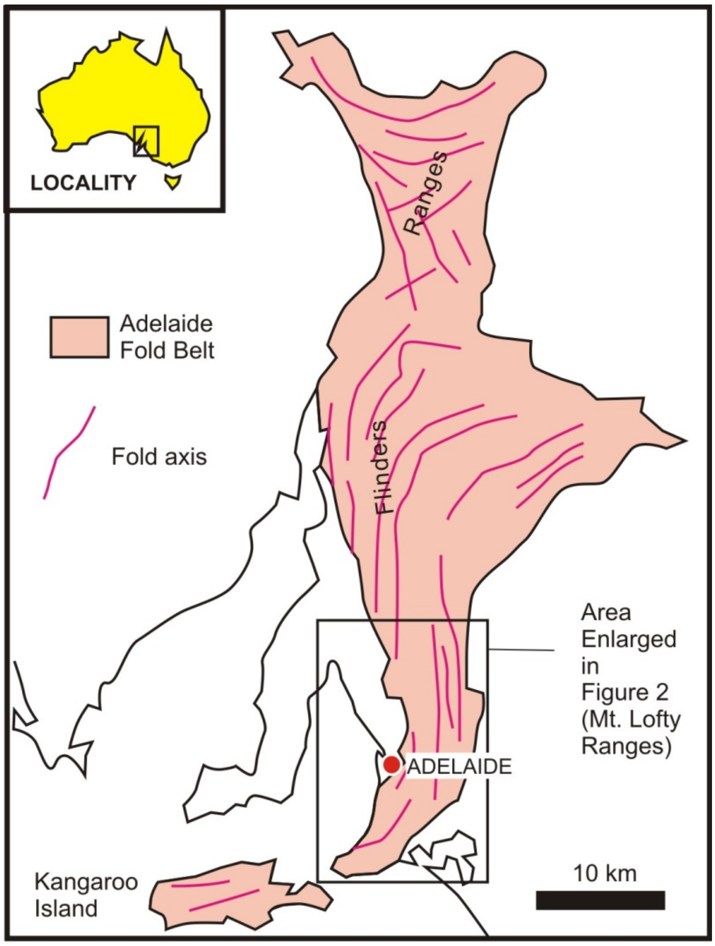

Figure 1. Location of the Adelaide Fold Belt in the Mount Lofty Ranges, Flinders Ranges, and Kangaroo Island.

Main content

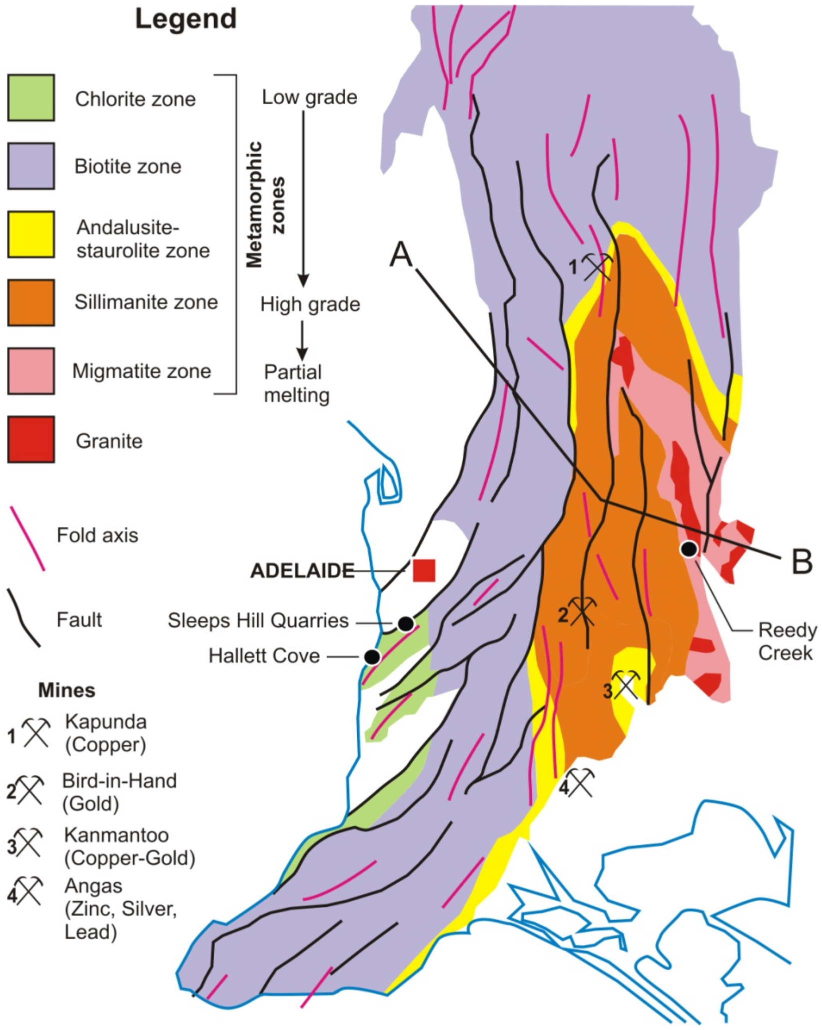

Figure 2. Simplified geological map of the Mount Lofty Ranges showing key features of the southern Adelaide Fold Belt.

Figure 2 is a simplified map of the Adelaide Fold Belt exposed at the surface of the earth in the Mount Lofty Ranges. The map highlights folds, faults, metamorphic zones, and igneous intrusions. Along the western, outer part of the fold belt, the rocks are folded and faulted, but are only slightly metamorphosed as indicated by the presence of the mineral chlorite. This part the fold belt is exposed in Sleeps Hill quarries (Figure 3). There, folds in quartzite and mudstone are up to several hundred metres across.

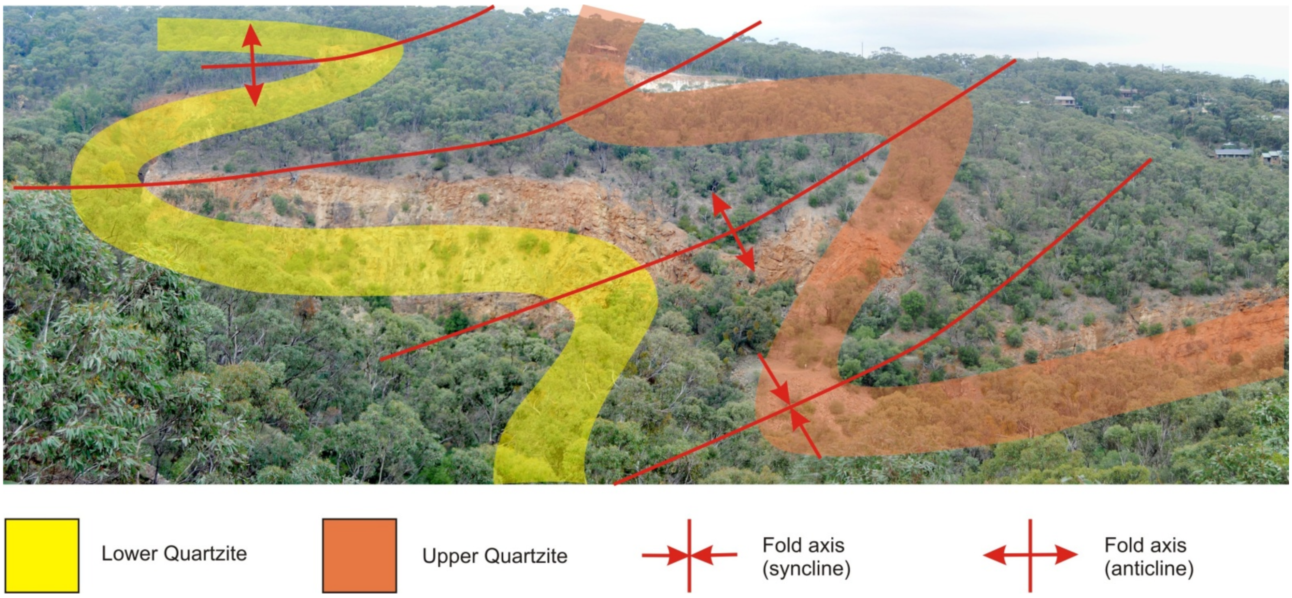

Figure 3. Large folds exposed in Sleeps Hill Quarries (see Figure 2 for location). Two quartzite units (shaded) have been mapped in and between the quarries. The poorly exposed rocks between the quartzite units are dominated by mudstone. Anticlines and synclines are indicated by geological symbols. The field of view is approximately 1,000 m across.

Further east toward the core of the fold belt, the progressive appearance of the metamorphic minerals biotite, staurolite, andalusite, and sillimanite reflect an increase in temperature and pressure i.e. metamorphic grade. Mudstone is now replaced by the metamorphic rocks phyllite, schist, and gneiss. The highest grade of metamorphic rock in the Adelaide Fold Belt is found in the migmatite zone. Migmatite is a coarse-grained metamorphic rock which forms when the metamorphic temperature is so high that the rock partially melts.

The core of the Adelaide Fold Belt is intruded by granite and similar igneous rocks collectively referred to as granitoids. Geochemical studies indicate that these igneous rocks originated mainly from partial melting of the mantle. They then migrated up into the core of the fold belt. Geochemistry of some of the granitioids indicates that surrounding fold belt rock was melted and incorporated into the magma. Depths of granitoid emplacement were 5-10 km below the Earth's surface.

Figure 4. The boundary between the Palmer Granite and migmatite is well exposed in the bed of Reedy Creek (see Figure 2 for location). The Reedy Creek area is within the core of the Adelaide Fold Belt where granite bodies intrude high grade metamorphic rocks. The arrow indicates the location of Figure 5.

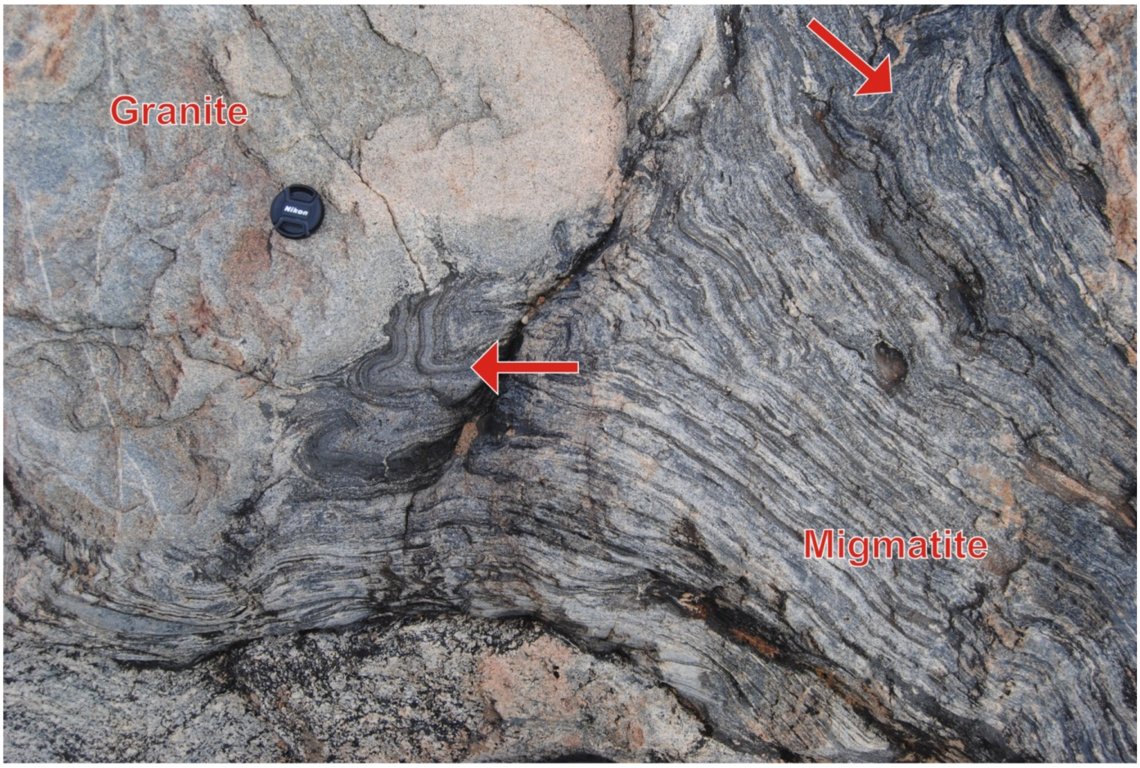

Figure 5. Close-up of the boundary between the Palmer Granite and migmatite. Partial melting is indicated by the contorted nature of the dark and light banding in the migmatite (examples arrowed) and the complex mixing of granite and migmatite along the boundary between these two rock types.

The boundary between the Palmer Granite and the surrounding migmatite is exposed in the bed of Reedy Creek (Figure 4). The migmatite has a banded appearance and contortions in the banding are evidence of its partially molten state (Figure 5). The progression to complete melting and incorporation into the granitiod magma is indicated by the intermingled boundary between these two rock types (Figure 5).

The heat associated with igneous activity and metamorphism results in the circulation of hydrothermal fluid. Chemical elements sourced from granitoids and other mountain belt rocks are incorporated into the circulating mineral-bearing fluids. Changes in physical and chemical conditions (e.g. decrease in temperature and pressure) can cause minerals, including metals and metal-bearing minerals, to precipitate. There are many deposits of copper, gold, zinc, lead, and silver in the Mount Lofty Ranges. Deposits that have been mined include Kapunda (copper), Kanmantoo (copper-gold), Angas (zinc-silver-lead), and Bird-in-Hand (gold) (Figure 2).

A plate tectonic explanation for the formation of the Adelaide Fold Belt has been provided by research geologists. Prior to about 514 million years ago the sedimentary basin known as the Adelaide Geosyncline was located along the south-east coast of Gondwana. About 514 million years ago subduction of oceanic lithosphere commenced that resulted in a change from a passive continental margin to a convergent plate tectonic boundary. Sedimentation in the Adelaide Geosyncline stopped, and mountain building processes commenced, in response to the convergent ('pushing together') plate tectonic forces. Radiometric dating of granitoids, which were emplaced during mounting building, indicates that mountain building continued for about 24 million years until 490 million years ago. The complexity of rock deformation and the intensity of metamorphism increased towards the deep core of the mountain belt. The core of the fold belt was intruded by granitoids. The overlying mountains were likely to have resembled a modern fold belt.

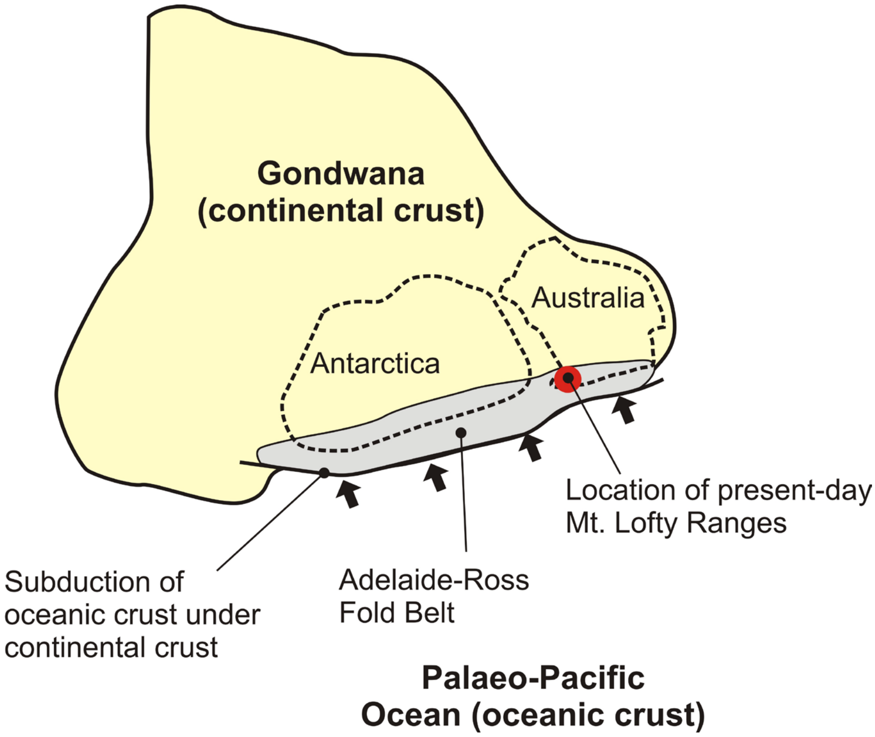

Figure 6. Plate tectonic reconstruction of Gondwana during formation of Adelaide-Ross Fold Belt (c. 514-490 million years ago). The outlines of Australia and Antarctica at this time are indicated.

A plate tectonic reconstruction (Figure 6) shows the position of Australia and Antarctica within the ancient super-continent of Gondwana. The Adelaide Fold Belt and its Antarctic counterpart, the Ross Fold Belt, are located along the south-east coast of Gondwana inboard of a subduction zone and overlooking the proto-Pacific Ocean. After mountain building ended, fragments of continental crust and a number of younger fold belts have been added to the eastern margin of Australia. Australia broke away from Antarctica about 56 million years ago during the breakup of Gondwana.

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Suggested Activities

1. Fold structures in the Adelaide Fold Belt are well exposed at Hallett Cove near Adelaide (Figure 7).
    a. On the photograph, draw lines along the folded bedding to define the shape of the folds. Some lines have been completed as a guide.
    b. Using Figure 3 as a guide, draw fold axes. Use the appropriate symbol to distinguish between anticlines and synclines.

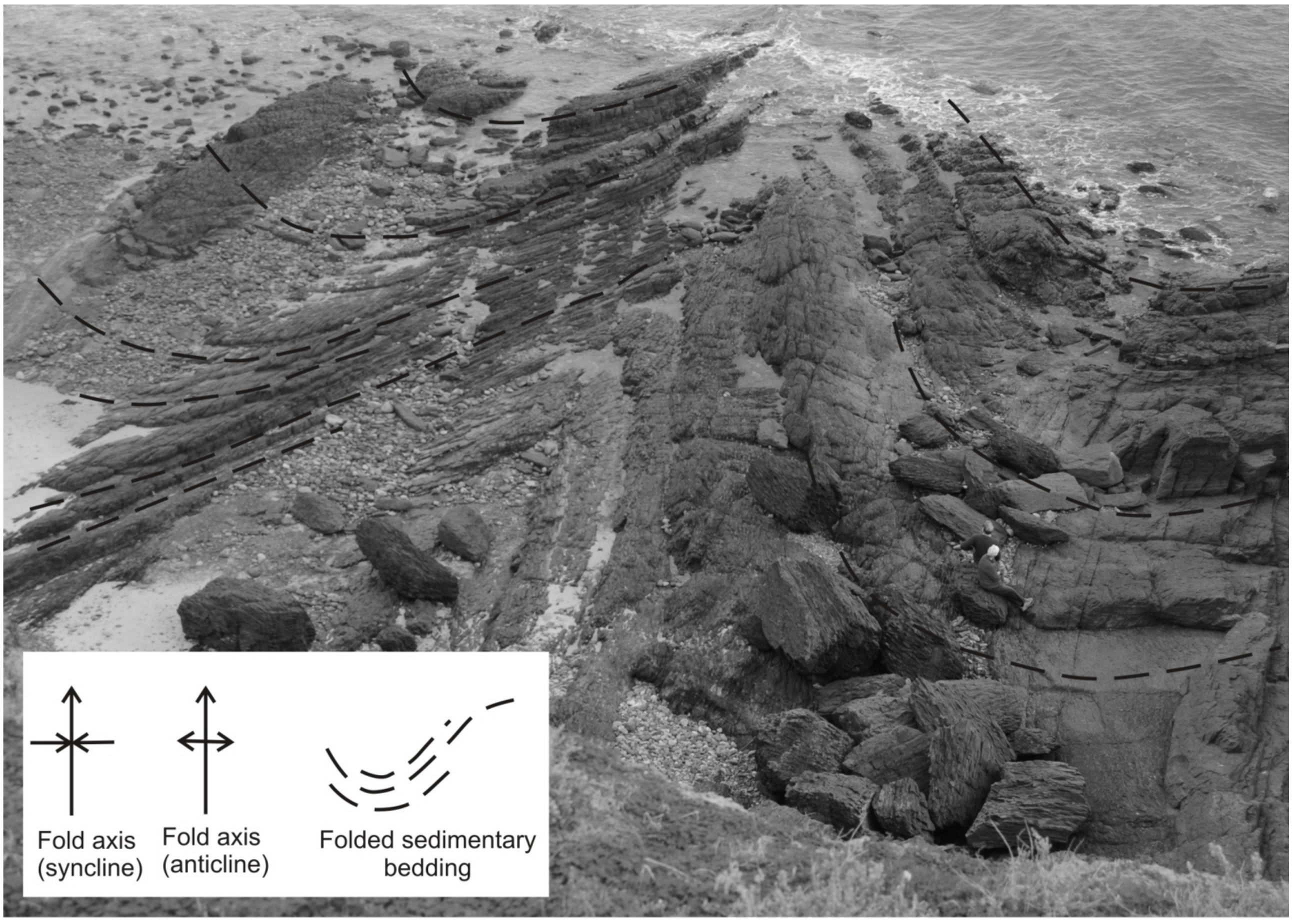

Figure 7. Folds exposed in the wave-cut platform at Hallett Cove (see Figure 2 for location). The photograph was taken from the top of a cliff. The people at right of centre indicate scale.

2. Study the cross-section of the Adelaide Fold Belt (Figure 8). Using the words from the “label list”, write labels in the boxes to highlight the various components of a fold belt.

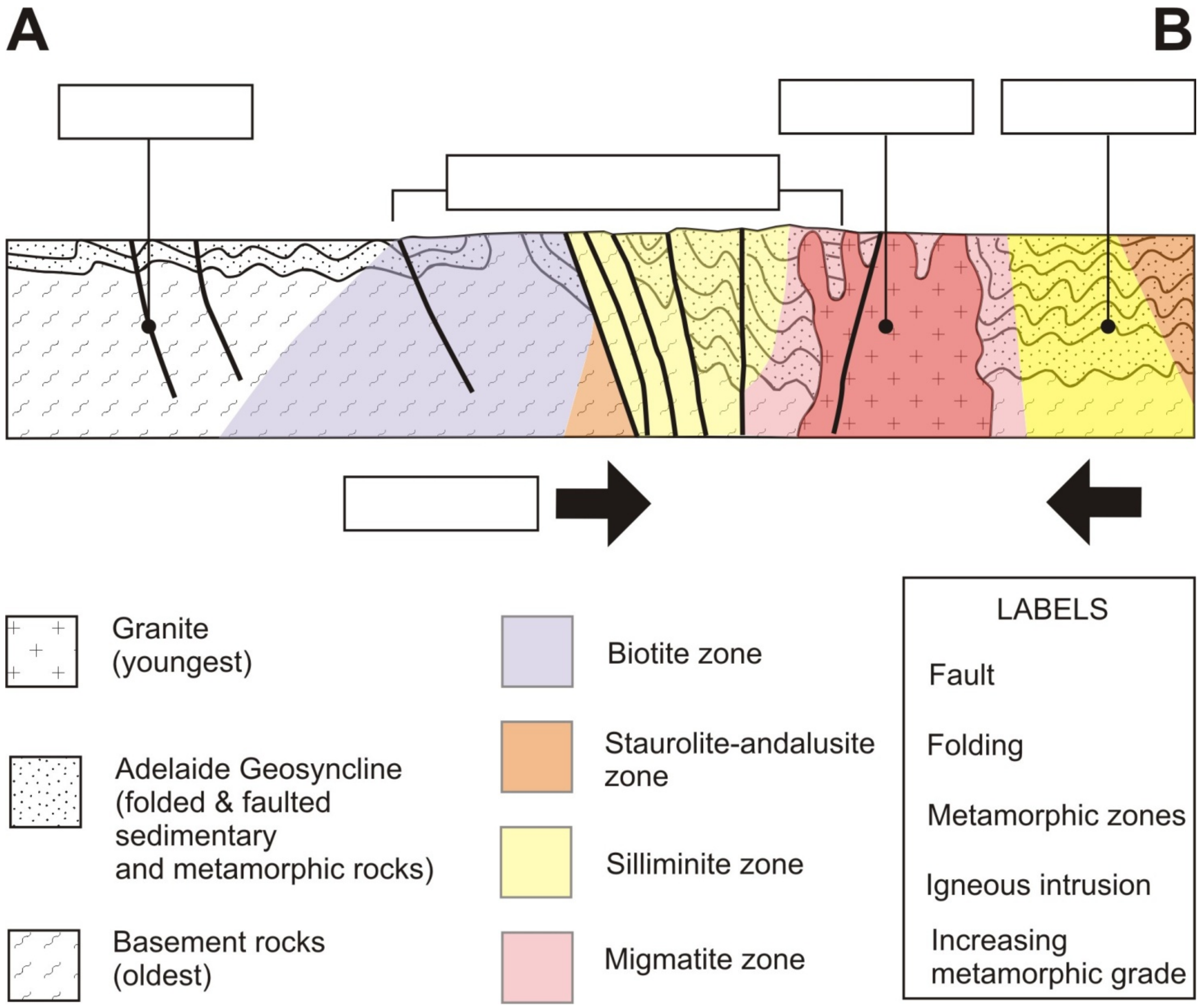

Figure 8. Cross-section across the southern Adelaide Fold Belt. The location of the cross-section is indicated in Figure 2.

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