Paired metamorphic belts

Paired metamorphic belts: are sets of parallel linear rock units that display contrasting metamorphic mineral assemblages. These paired belts develop along convergent plate boundaries where subduction is active. Each pair consists of one belt with a low-temperature, high-pressure metamorphic mineral assemblage, and another characterized by high-temperature, low-pressure metamorphic minerals.

Contents:

Historical background

The concept of paired metamorphic belts was originally theorized by the Japanese geologist, Akiho Miyashiro in 1961. The parallel arrangement between the metamorphic belts and the similar ages of each belt, led Miyashiro to the idea that metamorphic belts formed together as pairs.

Relation with plate tectonics

The introduction of the paradigm of plate tectonics in the late 1960s, led to a better understanding of regional metamorphism and permitted the association between paired metamorphic belts and subduction zones.

Conditions of formation

Subduction zone metamorphism

The asymmetric deformation of earth's lithosphere along subduction zones produces two distinct thermal environments. These two distinct thermal conditions are parallel to the trend of the subduction zone.

1. Low temperature, high pressure conditions are generated in the areas along the oceanic trench,
2. Whereas high temperature, low pressure conditions are generated beneath the arc region.

A positive thermal gradient is visualized, extending from the colder oceanic trench to the warmer arc region.

The thermal and barometric conditions within these 2 regions are recorded and preserved through distinct types of metamorphism and mineral assemblages.

Mineral assemblages

Detailed research on constraints of metamorphic mineral stability fields allows accurate inference of previous regional thermal and barometric conditions.

- Low temperature, high pressure conditions are characterized by blueschist facies and eclogite facies. Common minerals include: lawsonite, garnet, glaucophane, coesite, pumpellyite, and hematite. Such mineral assemblages indicate temperatures of 500-800 degree Celsius at pressure of 2.5-3.5 GPa.
- High temperature, low pressure conditions are characterized by granulite facies and amphibolite facies. Common mineral include: sillimanite, quartz, cordierite, orthopyroxenes. Such a mineral assemblage is indicative of temperatures reaching 1000 degrees Celsius at pressure of 0.5-1.3 GPa.

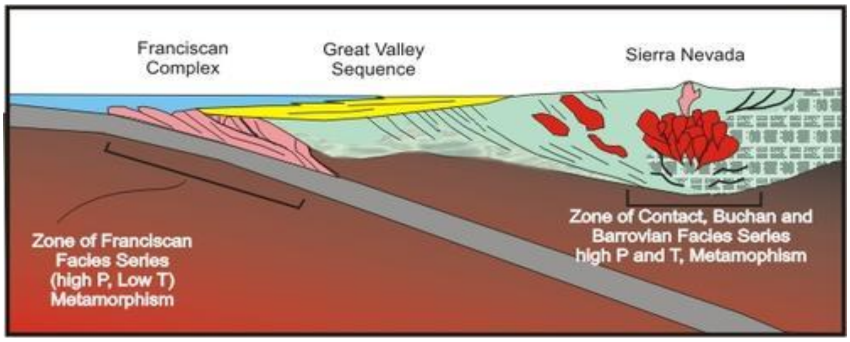
Geothermal gradient

Metamorphic belts are a consequence of thermal perturbations, due to low temperature with respect to pressure ratios (dT/dP) in oceanic trenches and high temperature with respect to pressure ratios (dT/dP) in arcs. Paired metamorphic belts are the product of subducted colder crustal rocks, which are taken to depth, metamorphosed and then exhumed. However, if the rock unit is not exhumed relatively quickly after subduction ceases, the rock unit will re-equilibrate to the standard geothermal gradient and the geological record will be lost.

Application

Paired metamorphic belts permit the inference of subduction directions and relative plate motions at various points in the past. For example, the Ryoke/Sanbagawa paired metamorphic belt in eastern Japan displays a metamorphic sequence indicating a north-west subduction direction. Whereas the Hidaka/Kamuikotu paired metamorphic belt on the western coast of Japan exhibits opposite orientation, indicating a different subduction direction. Furthermore, by dating paired metamorphic belts, the origin of present-day tectonic subduction mechanisms (asymmetric subduction) can be inferred.

Paired Metamorphic Belts



Metamorphic belt, Fanciscan Complex and sierra Navada

Franciscan melange in the Central Valley of California.

In 1961, Miyashiro noted that belts of high-pressure / low-temperature metamorphism on the oceanic side in the Circum-Pacific region were associated with belts of high-pressure / high-temperature metamorphism on the continental side.He termed such occurrences Paired Metamorphic Belts.Two examples include Japan, where the Sanbagawa Belt represents the high-pressure/low-temperature belt, and the adjacent Ryoke-Abukuma Belt, representing the low-pressure/high-temperature belt. The Ryoke-Abukuma belt consists of Barrovian- and Buchan-facies series metamorphic rocks. The other example is represented by the western U.S., where the Franciscan complex contains rocks metamorphosed at high pressure and low temperature, whereas rocks exposed in the Klamath Mountains and Sierra Nevada Mountains expose remnants of Barrovian- and Buchan-facies series metamorphic rocks.

The occurrences of paired belts have since been recognized throughout the world and include areas in New Zealand, Indonesia, Washington State in the U.S., Chile,Jamaica., the Alps of central Europe and the northern coast of South America.

Presence of hydrous minerals

Most of these areas show evidence of having been associated with convergent plate margins, where subduction has occurred. It appears that subduction is necessary to produce the low geothermal gradient necessary to form the belt of high pressure and low temperature. Such belts are quite rarely preserved in the geologic record due to the presence of hydrous minerals during blue schist-facies metamorphism. An exception takes place when these rocks are uplifted and exposed at the surface relatively fast after subduction ceases so that these rock units are able to escape being overprinted by facies of a normal geothermal gradient, as there would be still fluids available to form the green schist- and amphibolite-facies mineral assemblages.

Buchan facies series

The high-pressure, high-temperature belts are expected to form in areas beneath the island arc or continental margin volcanic arc. During emplacement of the arc, these areas are subject to higher-than-normal geothermal gradients that could produce Buchan-facies series metamorphic rocks. Furthermore, emplacement of batholiths and isostatic adjustment after magmatism has ceased due to the fact that these belts of high-T, high-P metamorphism were uplifted and exposed at the surface.

In the case of the Japanese paired belts, the two belts are adjacent to one another likely because subduction has moved farther off the coast. Compressional tectonics between the Pacific and Eurasian Plate has accreted the island arc and trench complex to Japan at the end of the Mesozoic.

In the case of the western U.S., the paired belts are separated from one another. This is because the oceanic ridge that existed off the western coast of North America was subducted, and the margin changed from dominated by compression and subduction to a transform-fault margin dominated by strike-slip faulting. Isostatic rebound of the highly deformed Franciscan Complex has resulted in its exposure at the surface.