

# PLATE TECTONIC CONFIGURATION OF GEMSTONES OF PAKISTAN

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Pakistan has seen a plethora of new discoveries of gemstones and fine mineral specimens over the past 25 years. The mineral wealth of the country occurs essentially in the Himalaya-Karakoram-Hindu Kush region (HKH), and the principal minerals include aquamarine, emerald, garnet, peridot, ruby, topaz, and tourmaline. But there are dozens of other minerals reported from over 100 localities, including minerals of the beryl, epidote, quartz, and spinel groups. Geological studies show that these minerals are directly related to the geodynamic evolution of the greater Himalayan orogen. The closure of the Neo-Tethys led to welding of (1) Karakoram plate to Kohistan magmatic arc along the Shyok suture during the Late Cretaceous, and (2) Indian plate to the Karakoram-Kohistan assembly during Paleocene-Early Eocene. These events were preceded, accompanied and followed by extensive magmatism and metamorphism that caused the genesis of the gemstones.

The southern margin of the Karakoram plate (in Hunza valley) and the northern margin of the Indian plate have passed through chlorite to sillimanite grade regional metamorphism. Marble beds near the Karakoram Batholith contain a good quality ruby, accompanied by spinel (red, brown, blue), and grass-green pargasite. As in Hunza, marbles in Nangi Mali (AJK), Kaghan and, possibly, Nanga Parbat (NP) also contain ruby corundum. Similar P-T conditions (600-650 °C, 5.5-6.5 kbar) have been proposed to have operated during their metamorphism. Tertiary magmatic activity in HKH was predominantly plutonic, and consisted of repeated pulses of granitic composition. These magmas were

seemingly derived from diverse source materials through different mechanisms. Some were related to subduction, some to anatexis during high grade metamorphism, and the Late Tertiary-Quaternary in the NP massif to rapid uplift. Small bodies of leucogranites, aplites, and pegmatites are abundant in NP, Kohistan arc, and Karakoram. A range of minerals has been reported from some of these pegmatites and associated quartz-feldspar (hydrothermal) veins: tourmaline (colourless, pink, green, black), aquamarine (sea blue to inky blue) and other Be-minerals (morganite, beryllonite, hamburgite, herderite), topaz (colourless, brown, honey), zoisite-epidote (pink, green), Mn-rich garnet, clear to coloured quartz (including amethyst), fluorite, moonstone, sphene, rutile, apatite, zircon, axinite, and many others. Of particular importance are the pegmatites (some zoned) on the eastern flank of the NP. High quality aquamarine and other minerals have also been reported from Shigar-Skardu, Hunza, Nagar, and Chitral. In Neelum valley, excellent crystals of yellowish to crimson red and tangerine garnet have been extracted from granitic pegmatites which may also have morganite, topaz and tourmaline. In Khaltoro area of NP, colourless to emerald beryl occurs in pegmatites and quartz-albite-tourmaline veins in amphibolites (the probable source of Cr) and granites. The gem pegmatites of northern Pakistan, fortunately, show little or no deformation. This suggests that they formed after the main phases of Cretaceous-Tertiary tectono-metamorphic activity. Age data are scanty, but the zoned pegmatites on the eastern flank of the NP are younger than 10 Ma.

Hydrothermal activity seems to be responsible for perhaps the most important gemstones of Pakistan. In addition to exquisite emerald, topaz, and peridot, there are reports of hydrothermal garnet (green, honey, brown), tourmaline (green), vesuvianite, epidote, and actinolite. With the exception of topaz, all these minerals occur in the Indus suture mélange. Emerald has been extracted from

magnesite-talc/quartz rocks, quartz (with or without carbonate) veins and, rarely, from chloritic rocks and chromitites in Swat, Mohmand and Bajaur. Needles of actinolite are associated with talc, whereas garnet and vesuvianite occur in metasomatised rocks. Further east in the suture zone at Sapat (Kaghan-Kohistan watershed), high quality peridot ( $Mg/(Mg+Fe) = 0.9$ ) and yellow to green chromian garnet occur in serpentine matrix with some magnetite and ludwigite. These suture zone minerals are associated with ultramafic rocks and are probably related to hydrothermal alteration of the latter. The Mingora emerald formation has been dated at 32 Ma. It is possible that beryllium and boron were carried by hydrothermal fluids either released from dehydration of the underlying Indian plate slab or are related to post-Early Tertiary magmatism.

An unusual topaz of high brilliance and light to deep pink colour occurs along with milky quartz in calcite veins near Katlang, Mardan. The country rocks are little-deformed limestone of the cover sequence of the Lesser Himalaya, and the topaz has been considered hydrothermal in origin. The source of the hydrothermal solutions is not known but they may be connected to the Late Paleozoic rift-related magmatism. Up to 1.2 cm long crystals of orange brown parasite reported from Mulagori may be associated with the Warsak alkaline granites of this age. If so, these will be the only gems in the HKH that are not related to the “Himalayan” tectonics.

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