Was There Pre-Collisional Metamorphism in Swat Pakistan?

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The Pakistan Himalaya in Swat is unusual because; 1) the metamorphic belt lies at the northern edge of the Indian plate in contact with metamorphosed ophiolitic mélange of the Indus suture zone; 2) metamorphism is no younger than middle Eocene; and 3) the primary structures consist of syn-metamorphic west-vergent folds and late-metamorphic N-S plunging open folds yet the metamorphic belt is bound in the south by the E-W trending Panjal-Khairabad thrust and in the north by the E-W trending Kohistan fault. The folds suggest E-W compression throughout metamorphism rather than N-S compression and south-vergence as might be assumed from the orientation of the two bounding faults. The Panjal-Khairabad thrust is post-metamorphic and, therefore, not associated with the syn-metamorphic structures. Instead, syn-metamorphic deformation is attributed to collision between the Indian plate and the Kohistan arc along the Kohistan fault. This collision is commonly assumed to be equivalent with India-Asia collision beginning between 57 and 50 Ma. The Kohistan fault, however, appears to be post-metamorphic and thus, not directly involved with metamorphism. This paper discusses the possibility that metamorphism in Swat began prior to India-Kohistan collision. Regional considerations suggest that the Swat rocks form the lower plate to eclogite-bearing thrust sheets of the Kaghan-Naran region.

West-vergent folds are well displayed in the Kotah and Loe Sar domes. Both consist of Swat augen-flaser gneiss of Middle Permian age (circa 265 Ma) unconformably overlain by Upper Permian-Triassic (and younger?) Marghazar, Kashala, and Saidu formations which, in turn, directly underlie the Indus Suture zone. An unconformity at the Swat gneiss-Marghazar contact is indicated by an absence of intrusive features across the contact, the presence of granitic pebbles in the Marghazar formation, and the large number of detrital zircon ages that cluster around the age of the Swat gneiss. The rock is interpreted as rift-related and correlative with the Panjal formation. A marker unit known as the amphibolite horizon is present everywhere at the top of the Marghazar formation in contact with overlying Kashala formation. It marks the stratigraphically highest position of any amphibolitic rock in Swat. Below the amphibolite horizon the Marghazar formation shows extreme thickness variation from almost zero to more than 300 m. Where it is thin, the Marghazar consists almost entirely of the amphibolite horizon which directly overlies Swat granitic gneiss. Where it is thick it consists of coarse-grained quartz-feldspar schist, schistose marble and amphibolite below the amphibolite horizon. The thickness variations are attributed to a combination of syn-depositional normal faulting (original thickness variations) and subsequent west-vergent recumbent folding. The folds nucleated as shear folds along the faulted, non-planar, Swat gneiss-Marghazar contact.

The Marghazar formation is overlain by marble and schistose marble of the Kashala formation. This rock contains Late Triassic fossils and represents the youngest shelf facies in northern Swat. The overlying Saidu formation consists of fine-grained graphitic phyllite and schist that may represent final drowning of the shelf. Its age is unknown. Regional foliation is continuous from Saidu formation into the overlying Indus suture zone suggesting that mélange matrix rocks were metamorphosed with the Indian plate during development of west-vergent folds and subsequent development of late-metamorphic N-S trending open folds. The Kohistan arc is separated from this deformation by the post-metamorphic Kohistan fault which truncates all structures on the Indian plate.

Northwest of the Kotah dome the Indus suture zone is overlain, not by the Kohistan arc, but by the Malakand fault slice which consists of Indian plate rock with a stratigraphy that is different from the Kotah dome. Another mélange unit, known as the Nawagai mélange, structurally overlies the Malakand slice. Both the Malakand and Nawagai faults are syn-metamorphic ductile contacts. This implies that suture zone mélange was imbricated with Indian plate rock during metamorphism. Regional relationships suggest that both the Malakand and Nawagai thrust sheets where transported toward the southeast in a direction nearly opposite to west-vergent folds exposed in the Kotah and Loe Sar domes. Both the

Malakand and Nawagai thrust sheets were folded across late-metamorphic N-S trending fold axes prior to truncation against the Kohistan fault.

The undeformed and unmetamorphosed Khar diorite intrudes the Nawagai mélange just south of the Kohistan fault near the Afghan border. This rock yielded a weighted mean $^{206}Pb/^{238}U$ age of 48.1 ±0.8 Ma which is interpreted to closely approximate the intrusive age. The circa 48 Ma age is consistent with an average SHRIMP age of 47±3 Ma from zircon rims obtained from the undeformed and unmetamorphosed Malakand granite (Smith and others, 1994) which intrudes across the Malakand slice. This constrains major deformation and metamorphism in both the Nawagai mélange and Indian plate to be 48 Ma or older. A $^{40}Ar/^{39}Ar$ date on hornblende from the Malakand slice gives a well-defined plateau age of 50±3.0 Ma indicating that the rocks had cooled below a maximum temperature of 570 °C by this time. Three somewhat variable pressure-temperature estimates were obtained from garnet-biotite-muscovite-plagioclase-quartz assemblages also from the Malakand slice; 610°C 9.5 kbar, 560°C 8.0 kbar, and 550°C 11.3 kbar. The lower two temperatures imply that the circa 50 Ma argon date records either crystallization of hornblende or cooling closely following crystallization. Peak temperatures close to the argon closure temperature of hornblende for at least part of the Malakand slice are suggested by a second $^{40}Ar/^{39}Ar$ hornblende date of 1040±20 Ma.

The available evidence suggests that major deformation and peak metamorphism in Swat had already occurred by 47-50 Ma and that the Kohistan arc was not directly involved. Instead, the metamorphism is attributed to underthrusting beneath ophiolitic mélange. It is possible that the Swat area is located inland from the buried northern margin of the Indian plate and, by 50 Ma, Kohistan had already collided with the Indian margin such that the arc was acting as a backstop to subduction of Swat rocks beneath ophiolitic mélange. It is equally possible, however, that syn-metamorphic deformation began with subduction or partial subduction beneath ophiolitic mélange prior to collision beginning as early as Late Cretaceous. Evidence for pre-Eocene metamorphism includes hornblende $^{40}Ar/^{39}Ar$ ages of 67±2 and 67±7 Ma from the eastern and western flanks of the Indus syntaxis (Treloar and Rex, 1990) and a concordant U-Pb zircon age of 88.7±0.4 Ma from within the Indus syntaxis (DiPietro and Isachsen, 2001). The data also leave open the possibility that the Kohistan arc collided much earlier than circa 54 Ma or that it collided much later. In all scenarios, final thrusting of Kohistan against Swat rocks was post-metamorphic. Rather than initiate metamorphism in Swat, final thrusting of Kohistan may have caused or initiated the exhumation and cooling of Swat rocks. This implies that the age of metamorphism in Swat and, by extrapolation, in the Kaghan-Naran area, should not be used as a constraint on India-Kohistan (or India-Asia) collision without additional corroborating evidence.

References

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