Spatial-temporal evolution of the Indus River and implications for western Himalayan tectonics: constraints from Sr-Nd isotopes and detrital zircon geochronology of Paleogene-Neogene rocks in the Katawaz basin, NW Pakistan

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The Indus River and its antecedence is controversially considered to have been draining various western Himalayan tectonic units since Indo-Asian initial contact and to have deposited sediments in intermontane basin within the suture zone, in the proximal foreland, and down to the Indian Ocean (Chirouze et al., 2014; Clift et al., 2001, 2002; Clift and Blusztajn, 2005; Henderson et al., 2010; Qayyum et al., 1996, 1997a, 1997b, 2001; Sinclair and Jaffey, 2001). Despite active research, fundamental questions regarding the river's origin and spatial-temporal evolution still remain open. The Cenozoic sedimentary sequence in the Katawaz Basin, NW Pakistan was thought to be a product of a fan-deltaic system, analogous to the modern Indus River system (Qayyum et al., 1996, 1997a, 1997b, 2001) and is critical for studying the Palaeo-Indus detritus transport history from source to sink. A preliminary study by Carter et al (2010) demonstrated that source sediment signatures were consistent with material derived from the nascent western Himalaya and associated magmatic arc but this study was based on too few samples to fully understand local changes in drainage and source contributions through time. To better understand the paleodrainage of the Indus River and its tectonic control, we conducted a detailed study of Sr-Nd isotopes and detrital zircons on Paleogene- to Neogene sedimentary rocks from the Katawaz Basin

In this study, we analyzed 22 bulk mudstone samples for Sr-Nd isotopes and 10 medium-grained sandstones for detrital zircon (U-Pb) geochronology. We refined the Cenozoic chronology in the Katawaz Basin based on our newly collected and compiled detrital zircon U-Pb ages and fission track ages. The prominent feature of this series is a positive excursion in Nd isotope value (ε_{Nd}) from ca. -10 to -5 starting in the Early Miocene (>19 Ma). Samples in this positive excursion also have relatively low $^{87}Sr/^{86}Sr$ values (0.7100 ~ 0.7200). We interpret this positive excursion in Nd isotope as reflecting a change in palaeodrainage from predominant input from the Karakoram or its possible western extension, the Helmand Block in Afghanistan (Boulin, 1988; Debon et al., 1987), possibly with a limited drainage area, to increasing contribution from Kohistan-Ladakh arcs that are characterized by high ε_{Nd} and low $^{87}Sr/^{86}Sr$ values. This shift towards increasing inputs from arcs is supported by our densely sampled detrital zircon U-Pb study of the same sedimentary rocks that shows a coincident change in U-Pb spectrum to dominant young zircon (<120 Ma) grains. This finding is consistent with a study on detrital sandstone framework mode in the upper stream, proximal foreland location, which reveals a change in sediment source to dominant arc detritus in the Early-Middle Miocene (Najman et al., 2003); and a new Hf-Sr study from the same location reveals that substantial input from arcs may last until the Middle-Late Miocene (Chirouze et al., 2014). The end of this positive excursion is accompanied by a shift in detrital zircon U-Pb mode towards more Himalayan-derived detritus dominated by old zircon (750-1,200 Ma) grains, possibly due to the stripping of the Kohistan-Ladak arc carapace that had been covering the Nanga Parbat syntaxis of Higher Himalaya affinity. Up-section, the recurrence of dominant young zircons with Neogene grains typical of the present Indus (Alizai et al., 2011), suggests the construction of the modern drainage of the Indus by then, with later eastward shifting of the lower Indus due to eastward propagation of the adjacent Baluchistan thrust belt.

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References

Alizai, A., Carter, A., Clift, P.D., VanLaningham, S., Williams, J.C. and Kumar, R., 2011, Sediment provenance, reworking and transport processes in the Indus River by U–Pb dating of detrital zircon grains, Global and Planetary Change, 76, 33-55.

Boulin, J., 1988, Hercynian and Eocimmerian events in Afghanistan and adjoining regions, Tectonophysics, 148, 253-278.

Carter, A., Najman, Y., Bahroudi, A., Bown, P., Garzanti, E. and Lawrence, R.D., 2010, Locating earliest records of orogenesis in western Himalaya: Evidence from Paleogene sediments in the Iranian Makran region and Pakistan Katawaz basin, Geology, 38, 807-810.

Chirouze, F., Huyghe-Mugnier, P., Chauvel, C., van der Beek, P., Bernet, M. and Mugnier, J.-L., 2014, Stable drainage pattern and variable exhumation in the western Himalaya since the Middle Miocene, J. Geol., under revision.

Clift, P., Shimizu, N., Layne, G., Blusztajn, J., Gaedicke, C., Schlüter, H.-U., Clark, M. and Amjad, S., 2001, Development of the Indus Fan and its significance for the erosional history of the Western Himalaya and Karakoram, Geol. Soc. Am. Bull., 113, 1039-1051.

Clift, P.D. and Blusztajn, J., 2005, Reorganization of the western Himalayan river system after five million years ago, Nature, 438, 1001-1003.

Clift, P.D., Carter, A., Krol, M. and Kirby, E., 2002, Constraints on India-Eurasia collision in the Arabian Sea region taken from the Indus Group, Ladakh Himalaya, India, In: Clift, P.D., Carter, A., Krol, M., and Kirby, E. (eds.), The tectonic and climatic evolution of the Arabian Sea region, Geological Society Special Publication, 195, 97-116.

Debon, F., Afzali, H., Le Fort, P. and Sonet, J., 1987, Major intrusive stages in Afghanistan: Typology, age and geodynamic setting, Geologische Rundschau, 76, 245-264.

Henderson, A.L., Najman, Y., Parrish, R., BouDagher-Fadel, M., Barford, D., Garzanti, E. and Andò, S., 2010, Geology of the Cenozoic Indus Basin sedimentary rocks: Paleoenvironmental interpretation of sedimentation from the western Himalaya during the early phases of India-Eurasia collision, Tectonics 29.

Najman, Y., Garzanti, E., Pringle, M., Bickle, M., Stix, J. and Khan, I., 2003, Early-Middle Miocene paleodrainage and tectonics in the Pakistan Himalaya, Geol. Soc. Am. Bull., 115, 1265-1277.

Qayyum, M., Lawrence, R.D. and Niem, A.R., 1997a, Discovery of the palaeo-Indus delta-fan complex, J. Geol. Soc., 154, 753-756.

Qayyum, M., Lawrence, R.D. and Niem, A.R., 1997b, Molasse-Delta-flysch continuum of the Himalayan orogeny and closure of the Paleogene Katawaz Remnant Ocean, Pakistan, Intern. Geol. Rev., 39, 861-875.

Qayyum, M., Niem, A.R. and Lawrence, R.D., 1996, Newly discovered Paleogene deltaic sequence in Katawaz basin, Pakistan, and its tectonic implications, Geology, 24, 835-838.

Qayyum, M., Niem, A.R. and Lawrence, R.D., 2001, Detrital modes and provenance of the Paleogene Khojak Formation in Pakistan: Implications for early Himalayan orogeny and unroofing, Geol. Soc. Am. Bull., 113, 320-332.

Sinclair, H. and Jaffey, N., 2001, Sedimentology of the Indus Group, Ladakh, northern India: implications for the timing of initiation of the palaeo-Indus River, J. Geol. Soc. 158, 151-162.