Constraints to the timing of India–Eurasia collision? a re-evaluation of evidence from the Indus Basin sedimentary rocks of the Indus–Tsangpo Suture Zone, Ladakh, India.

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The Cenozoic Indus Basin Sedimentary Rocks (IBSR) are preserved in the Indus Suture zone, Ladakh. They have been used in previous research to constrain the timing of India-Asia collision as having occurred by 50 Ma, based on provenance studies which determine the earliest occurrence of mixed Indian and Asian detritus in the sedimentary record (Clift, 2002), and/or earliest evidence of Asian detritus deposited on the Indian plate (Clift, 2002; Clift et al., 2001). Our new study (Henderson et al., 2010a; Henderson et al., 2010b; Henderson et al., 2011) disagrees with these previous findings and we conclude that the sedimentary record in this region cannot be used to constrain India-Asia collision at 50 Ma in the manner previously utilised.

The Chogdo Formation of the IBSR, lying immediately beneath the 50 Ma aged Nummulitic limestone (Green et al., 2008), is proposed to contain both Indian (ophiolitic) and Asian (granitoid) derived material (Clift, 2002), and to lie in sedimentary contact with the underlying Indian plate Lamayuru Formation and ophiolitic melange (Clift, 2002; Clift et al., 2001), thus apparently providing two constraints to the time of collision.

Using the provenance techniques we employed (U-Pb on detrital zircon, Sm-Nd on detrital apatite), we were unable to discern any unequivocal evidence of Indian detritus in the Chogdo Formation, and concur with previous work (Wu et al., 2007), that interprets the Formation as overwhelmingly Asian-derived. We suggest that the ophiolitic detritus recorded in the Chogdo Formation, previously interpreted as derived from the Indian plate Spontang ophiolite, could equally well be derived from local sources in the suture zone, associated with the Dras arc, and do not provide conclusive evidence of Indian input. Thus we do not consider that the Chogdo Formation constrains the time of collision by containing both Indian and Asian detritus.

Given the overwhelmingly Asian provenance of the Chogdo Formation, its proposed stratigraphic position, in sedimentary contact with the underlying Indian plate, would provide another line of evidence to date the time of collision at prior to 50 Ma. For this evidence to be upheld, it must be shown that a) the material beneath the contact is indeed Indian rather than Asian plate, b) the material above the contact is indeed Chogdo Formation rather than younger Indus Basin Sedimentary rocks and c) that the contact is sedimentary rather than tectonic. After characterising the sedimentology, and isotopic, geochemical and petrographic signatures, of the various Indus Basin Sedimentary Rocks in the "type section" in the Zanskar River gorge, we studied the critical basal contact of the Chogdo at the three locations where previous work had indicated the formation lay over Indian plate Lamayuru Formation or ophiolitic melange associated with the Indian plate. These locations lie between the villages of Upshi and Lato on the Manali-Leh highway and between the villages of Chilling and Sumda in the Zanskar Gorge.

At the first location, on the Manali-Leh Highway, we consider that the Formation below the contact (which we suggest is a tectonised unconformity) is IBSR rather than Lamayuru Formation, based on the U-Pb ages of its detrital zircons, and its petrography, which show Asian rather than Indian affinities. We agree with previous work, that the formation above the contact is IBSR, as evidenced by its Asian-derived signature. However, the presence of mudstone enriched in Cr and Ni, limestone conglomerate clasts, detrital white micas, petrography with characteristics of a dissected arc provenance, absence of interbedded limestones, and the presence of a 48.4 +/-1.4 Ma detrital zircon makes the suggested correlation of this unit to the 50 Ma aged Chogdo Formation with its undissected arc petrography,

unenriched Cr and Ni concentrations and interbedded limestone units, unlikely. Rather, we prefer to correlate this unit with younger sediments higher up the IBSR succession.

At the second location, near the villages of Chilling and Sumda, the Chogdo Formation is considered to lie in sedimentary contact above both the Lamayuru Formation and Indian plate ophiolitic melange. However, our provenance analysis, based on petrography and U-Pb ages of detrital zircons, indicate that the unit above the contact is of Indian rather than Eurasian plate derivation, entirely unlike the defined Eurasian-derived Chogdo Formation in the "type section" of the Zanskar Gorge. We therefore do not consider it to be Chogdo Formation and this location cannot be used to constrain the timing of India-Asia collision in the manner previously proposed.

We therefore conclude that there is currently no evidence in the region for mixing of Indian and Eurasian detritus in the >50 Ma aged Chogdo Formation, nor evidence for Asian-derived Chogdo Formation overlying Indian plate in sedimentary contact. Thus, previously proposed constraints to the time of collision at ca 50 Ma, based on these data, in our view should be reconsidered.

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