Provenance of Lower Cretaceous quartz arenites from the northern Indian Plate: tropical weathering or a multi-cycled sediment source?

Hazel Beaumont[1, 2*], Stuart D. Burley[2 & 3], Thomas Gould[4] and Stuart M. Clarke[2]

[1] Department of Geography and Environmental Management | University of the West of England | Bristol
[2] Basin Dynamics Research Group | Keele University | Staffordshire
[3] Orient Petroleum Limited | Pakistan
[4] RPS Ichron | Cheshire
* hazel.beaumont@uwe.ac.uk

Lower Cretaceous sediments of the northwestern Indian Plate margin were deposited in the Barmer, Cambay, Narmada, Kachchh and Jaisalmer basins (Figure 1) of the West Indian Rift System (WIRS) and the Lower and Middle Indus Basins (LMIB; Figure 1). These fluvial and coastal plain sediments are dominated by mature quartz arenites (Baig et al., 2016). Such an extreme quartz-rich detrital mineralogy is surprising, given that the local highs flanking the WIRS comprise a variety of Precambrian basement rocks including the Malani Igneous Suite, the Delhi Supergroup, the Aravalli Mobile Belt, the Bundelkhand Craton and the Cambrian sediments of the Marwar Supergroup (Figure 2). Most published studies assume that the main source area for these quartz arenites is the Aravalli Mobile Belt, although there is little palaeogeographical or mineralogical evidence to support this. Presented here are new mineralogical data for the fluvial Ghaggar-Hakra Formation (Figure 3) of the Barmer Basin and a compilation of published detrital mineralogies of sandstones across the WIRS and LMIB, which are laterally equivalent to the Ghaggar-Hakra Formation. The aim here is to constrain the main provenance source areas during the Lower Cretaceous.

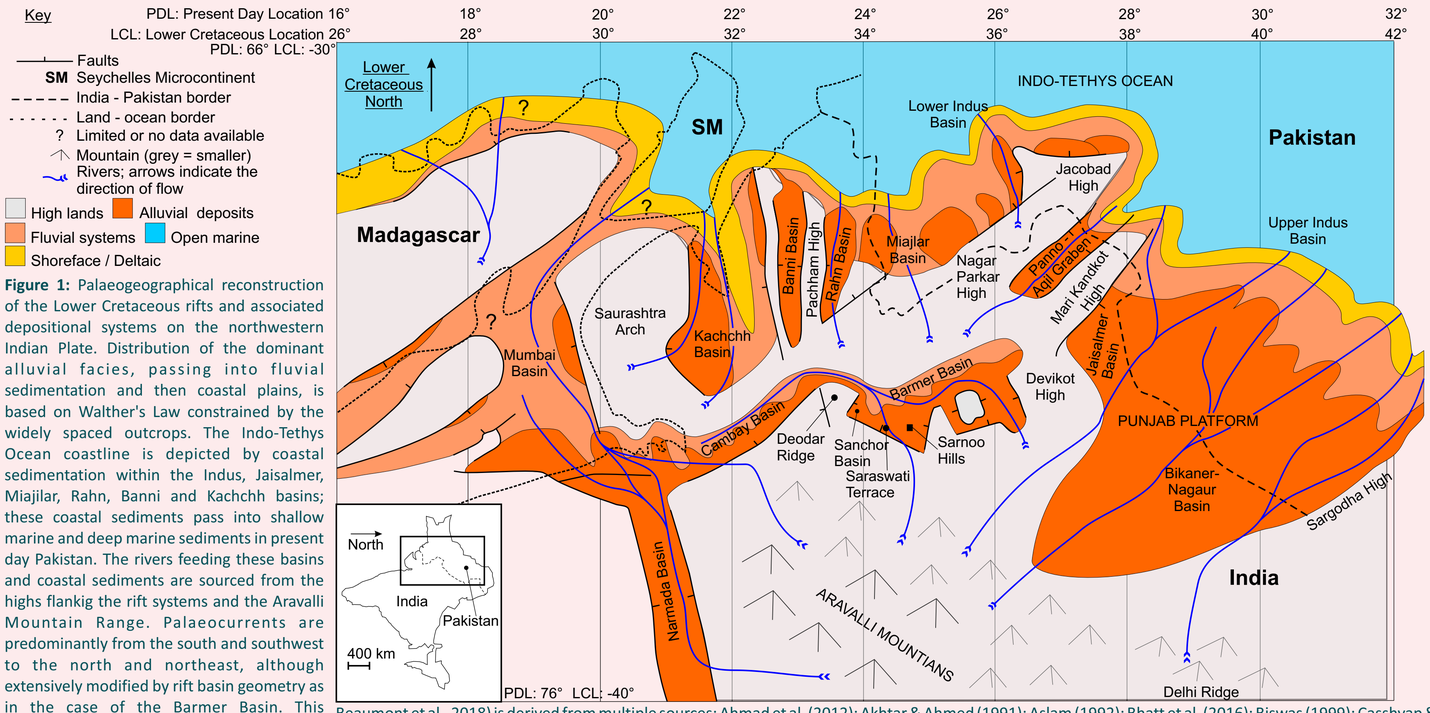


Figure 1: Palaeogeographical reconstruction of the Lower Cretaceous rifts and associated depositional systems on the northwestern Indian Plate. Distribution of the dominant alluvial facies, passing into fluvial sedimentation and then coastal plains, is based on Walther's Law constrained by the widely spaced outcrops. The Indo-Tethys Ocean coastline is depicted by coastal sedimentation within the Indus, Jaisalmer, Miajilar, Rahn, Banni and Kachchh basins; these coastal sediments pass into shallow marine and deep marine sediments in present day Pakistan. The rivers feeding these basins and coastal sediments are sourced from the highs flankig the rift systems and the Aravalli Mountain Range. Palaeocurrents are predominantly from the south and southwest to the north and northeast, although extensively modified by rift basin geometry as in the case of the Barmer Basin. This palaeographical reconstruction (from Beaumont et al., 2018) is derived from multiple sources: Ahmad et al. (2012); Akhtar & Ahmed (1991); Aslam (1992); Bhatt et al. (2016); Biswas (1999); Casshyap & Aslam (1992); Chatterjee et al. (2013); Khalid et al. (2014); Kothari et al. (2015); Mukherjee (1983); Racey et al. (2016); Rai et al. (2013); Rajaram et al. (2017); Rao et al. (2015).

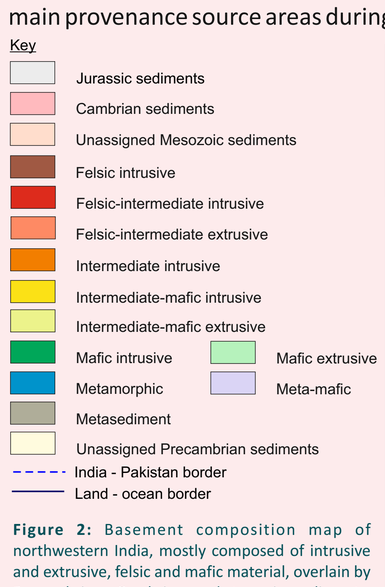
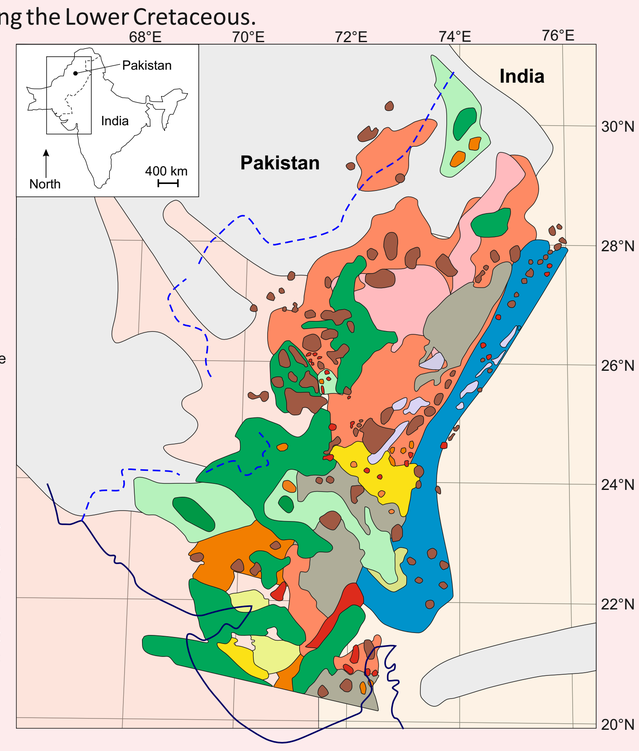


Figure 2: Basement composition map of northwestern India, mostly composed of intrusive and extrusive, felsic and mafic material, overlain by Precambrian, Cambrian and Jurassic sediments, based on Hus and Cathro, 2010; Roy and Jakhar, 2002. Inset of India in the top left corner displaying the location context and the India – ocean and the Indian – Pakistan border.



Petrography

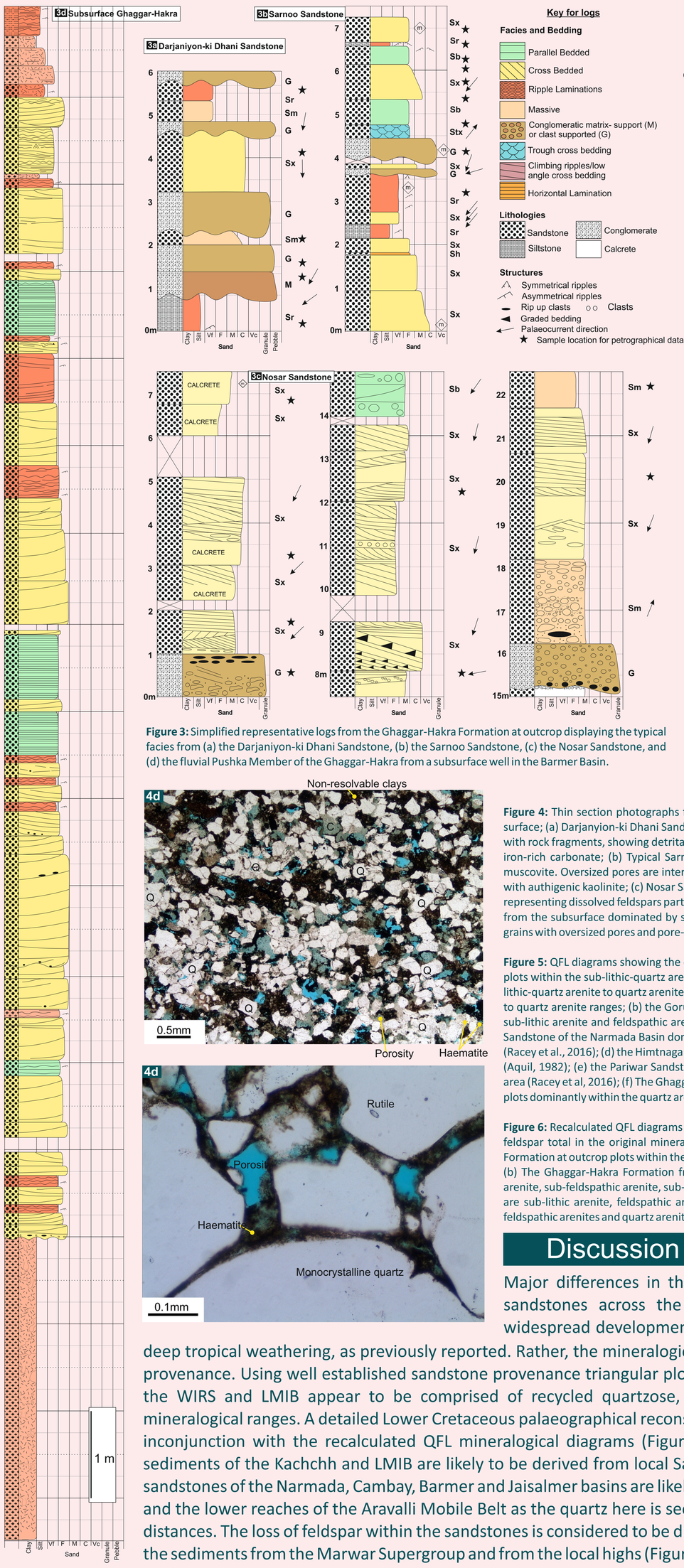


Figure 3: Simplified representative logs from the Ghaggar-Hakra Formation at outcrop displaying the typical facies from (a) the Darjaniyon-ki Dhani Sandstone, (b) the Sarnoo Sandstone, (c) the Nosar Sandstone, and (d) the fluvial Pushka Member of the Ghaggar-Hakra from a subsurface well in the Barmer Basin.

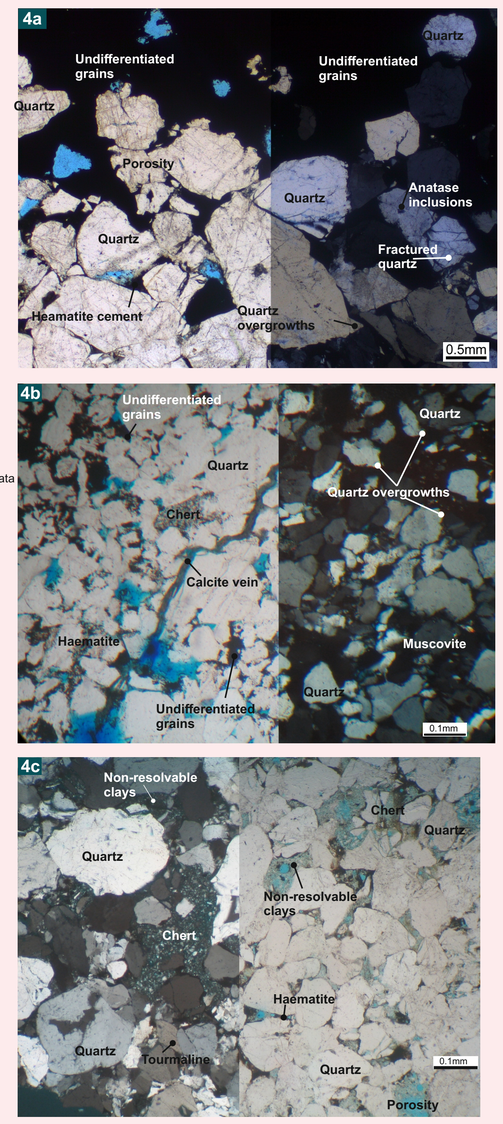


Figure 4: Thin section photographs from the Ghaggar-Hakra Formation, at both the outcrop and sub-surface; (a) Darjanyion-ki Dhani Sandstone quartz arenite displaying dominance of detrital quartz grains with rock fragments, showing detrital grains coated by authigenic haematite, probably a replacement of iron-rich carbonate; (b) Typical Sarnoo sandstone dominated by detrital grains of quartz and minor muscovite. Oversized pores are interpreted to be feldspar dissolution porosity some of which are filled with authigenic kaolinite; (c) Nosar Sandstone dominated by detrital quartz grains, with oversized pores representing dissolved feldspars partially filled with authigenic kaolinite, and; (d) Fine-grained sandstone from the subsurface dominated by strained monocrystalline quartz and sutured polycrystalline quartz grains with oversized pores and pore-filling kaolinite with haematite replacement detrital clay laminae.

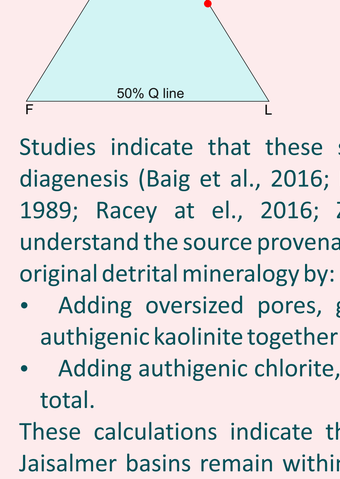


Figure 5: QFL diagrams showing the composition of each sandstone; (a) Darjaniyon-ki Dhani Sandstone plots within the sub-lithic-quartz arenite to quartz arenite area, Sarnoo Sandstone plots within the sub-lithic-quartz arenite to quartz arenite area, the Nosar Sandstone plots within the sub-lithic-quartz arenite to quartz arenite ranges; (b) the Goru Sandstone of the Lower and Middle Indus Basins plots within the sub-lithic arenite and feldspathic arenite area (Berger et al., 2009 and Baig et al., 2016); (c) the Nimar Sandstone of the Narmada Basin dominantly plots within the quartz arenite and sub-lithic arenite areas (Racey et al., 2016); (d) the Himtnagar Sandstone of the Cambay Basin plots within the felds arenite range (Aquil, 1982); (e) the Pariwar Sandstone of the Jaisamler Basin plots within the sub-feldspathic arenite area (Racey et al, 2016); (f) The Ghaggar-Hakra Formation from the subsurface of the Barmer Basin which plots dominantly within the quartz arenite and sub-lithic arenite areas.

For the Ghaggar-Hakra Formation 99 thin sections (Figure 4) from both outcrop and core were point-counted. Virtually all the samples are quartz arenites or sublithic arenites with almost no detrital feldspar (see Figures 4 and 5). Published data for the WIRS indicates that the sandstones are predominantly quartz arenites or sub-lithic arenites (Figure 5), apart from in the Kachchh Basin which has an arkosic detrital composition (Figure 5). The LMIB sandstones are mineralogically classified as sub-lithic arenites (Figure 5).

Pre-diagenesis

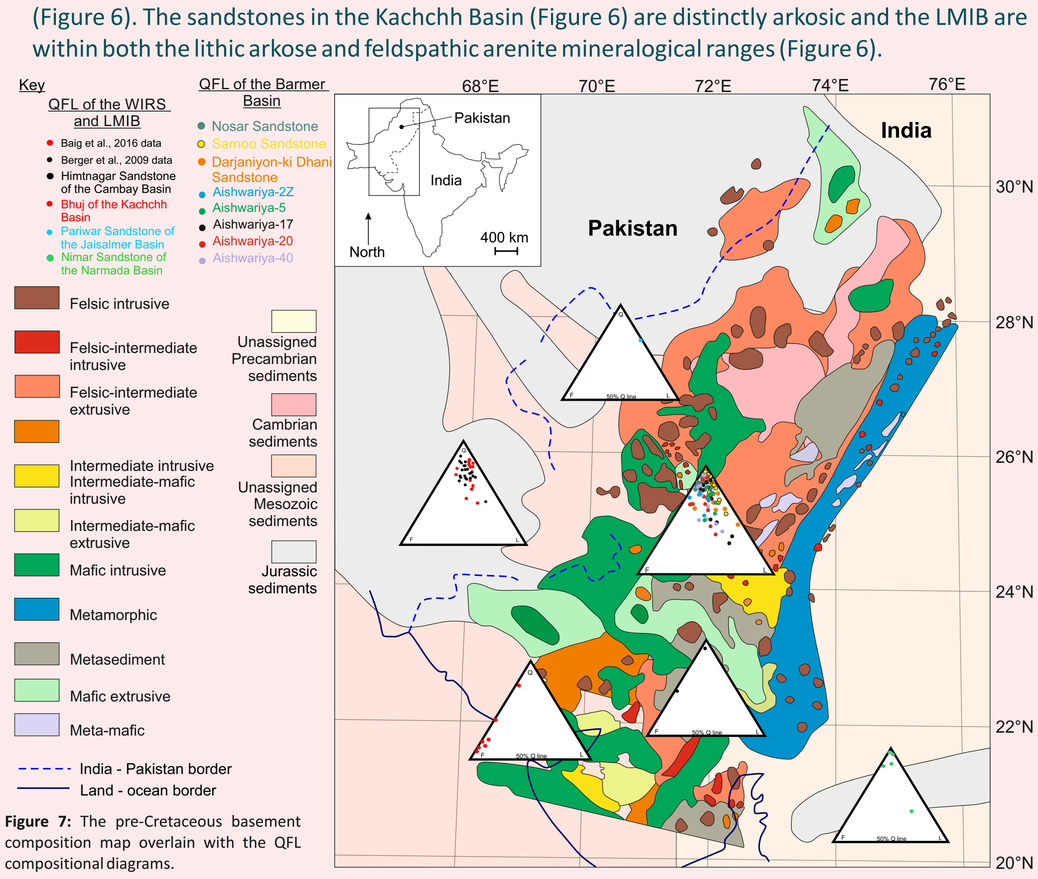


Figure 6: Recalculated QFL diagrams in which oversized pores and authigenic kaolinite are added to the feldspar total in the original mineralogy (full method is set out in the text); (a) The Ghaggar-Hakra Formation at outcrop plots within the quartz arenite, sub-feldspathic arenite and sub-lithic arenite fields; (b) The Ghaggar-Hakra Formation from the subsurface of the Barmer Basin plots within the quartz-arenite, sub-feldspathic arenite, sub-lithic arenite and feldspathic arenite; (c) the sediments of the LMIB are sub-lithic arenite, feldspathic arenite and lithic arenite, and; (d) the sediments of the WIRS are feldspathic arenites and quartz arenites (Racey et al., 2016 and Aquil, 1982).

Discussion and conclusions

Major differences in the detrital mineralogy of Lower Cretaceous sandstones across the northern Indian Plate indicate that the widespread development of quartz arenites cannot be the result of deep tropical weathering, as previously reported. Rather, the mineralogical differences reflect variation in the source provenance. Using well established sandstone provenance triangular plots, the Lower Cretaceous sandstones within the WIRS and LMIB appear to be comprised of recycled quartzose, dissected arc and transitional continental mineralogical ranges. A detailed Lower Cretaceous palaeographical reconstruction of the northern Indian Plate margin inconjunction with the recalculated QFL mineralogical diagrams (Figure 1 and 7) suggests the Lower Cretaceous sediments of the Kachchh and LMIB are likely to be derived from local Saurashtra and Nagar-Parkar, highs whilst the sandstones of the Narmada, Cambay, Barmer and Jaisalmer basins are likely to be derived from the Marwar Supergroup and the lower reaches of the Aravalli Mobile Belt as the quartz here is second generation and has likely travelled long distances. The loss of feldspar within the sandstones is considered to be due to in-situ diagenesis and transportation of the sediments from the Marwar Supergroup and from the local highs (Figures 1, 2 and 7).

Studies indicate that these sediments have been affected by diagenesis (Baig et al., 2016; Bose et al., 1986; Desai and Desai, 1989; Racey at el., 2016; Zaighama and Mallick, 2000). To understand the source provenance it is necessary to reconstruct the original detrital mineralogy by:

- Adding oversized pores, grain-replacive calcite cement and authigenic kaolinite together to the original feldspar content, and;
- Adding authigenic chlorite, smectite, opaque minerals and iron-replaced grains to the lithic total.

These calculations indicate that the sandstones from the Barmer, Cambay, Narmada and Jaisalmer basins remain within the quartz arenite and sub-lithic arenite mineralogical ranges (Figure 6). The sandstones in the Kachchh Basin (Figure 6) are distinctly arkosic and the LMIB are within both the lithic arkose and feldspathic arenite mineralogical ranges (Figure 6).

Figure 7: The pre-Cretaceous basement composition map overlain with the QFL compositional diagrams.

References and Acknowledgements

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UWE Bristol University of the West of England
CAIRN WE FUEL AMAZING
ichron part of the RPS Group
BASIN DYNAMICS RESEARCH GROUP BDRG