

Diagenesis of the Oligocene-Early Miocene Panjgur Formation, Paleocene Ispikan Formation and Wakai Exotic Blocks in the Makran Accretionary Belt, Southwest Pakistan*

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Abstract

The Oligocene-Early Miocene Panjgur Formation is exposed in the Makran accretionary wedge in southwest Pakistan. Isolated, pre-Oligocene exotic blocks, the Ispikan Formation and Wakai exotic blocks, also crop out in the area. Petrographic and geochemical evidence indicate that the Panjgur and Ispikan detritus was transported from the Himalaya-Karakorum-Hindukush orogen southward and deposited as a deep marine turbidite complex in the northeast-southwest aligned Katawaz remnant ocean and east-west aligned Makran trench. The Bela-Muslimbagh ophiolites, associated mélanges to the east, and the Chaghai-Raskoh volcanic arc to the west contributed mafic to ultramafic detritus to the Panjgur and Ispikan sediments.

Sandstones of the Wakai exotic blocks, rich in mafic volcanic fragments and associated with sheared mafic volcanic rocks, purple colored shale, chert, marble, and pelagic limestone, suggest obduction of oceanic crust of the Gulf of Oman. The tectonics of these sandstones has led to a complex diagenetic history. Cements include ferroan>nonferroan calcite, ankerite, dolomite, and chlorite>illite with carbonate cements dominant in the Panjgur and Ispikan formations, and chlorite dominant in the Wakai exotic blocks. Physical compaction preceded cementation in the Panjgur and Ispikan Formations. Early nonferroan calcite inhibited physical compaction in the Wakai exotic blocks. Secondary porosity developed during dissolution of nonferroan calcite, feldspars, and rock fragments and was later destroyed by precipitation of chlorite, ferroan calcite, ankerite, and dolomite. Chlorite predates ferroan calcite, and both show signs of a second stage of dissolution with chlorite filling secondary pores in a nonchlorite-like I-beam morphology. Ankerite and dolomite formed late, replaced earlier stages of calcite, framework grains, and filled secondary pores.

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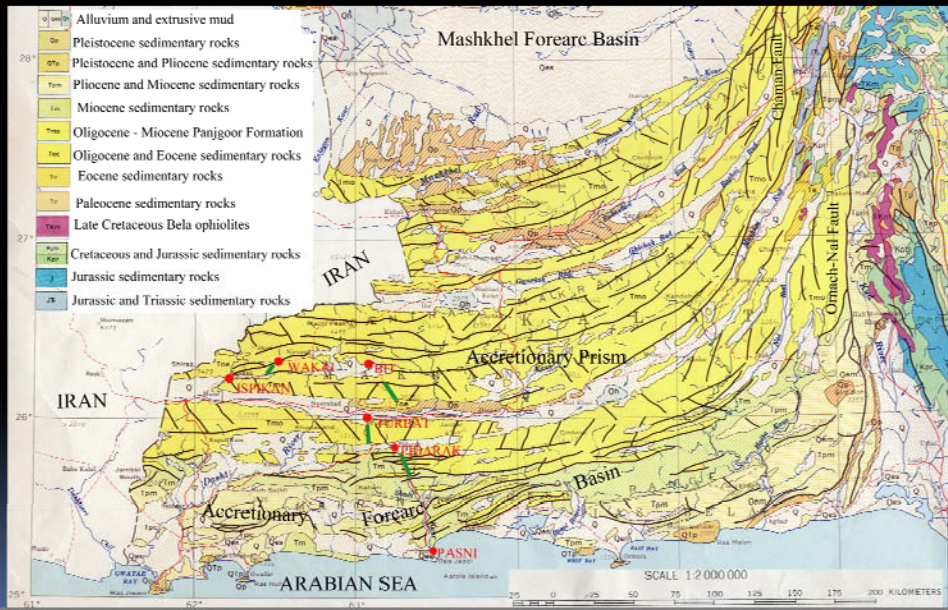
Dr. A. Salam Khan

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University of
Balochistan**

Sample Locations



Geologic Setting



Geological map of the southern Balochistan (modified after the Geological Map of Pakistan, Bakr and Jackson 1964), showing positions of the studied sections (green colored lines) near Wakai, Bit, Turbat, and Pidarak.

Stratigraphy

Age	Group	Formation	Lithology
Oligocene-Miocene	Turbat	Panjgur Fm	SS interbedded with Shale
U. Eocene-L. Oligocene		Hoshab Shale	Shale w/thin bedded SS
		<i>Thrust</i>	
Eocene		Wakai LS	Fossiliferous LS
		<i>Thrust</i>	
Paleocene		Ispikan Fm	Cong., SS, shale
		<i>Thrust</i>	
Cretaceous-Paleocene		Wakai Exotic Blocks	Agglom, purple sh, marl, chrt, pelagic LS, marble, mafic rx

Travel



Field work

Wakai Exotic Blocks



Outcrop of Wakai Exotic Block, Wakai Village



Field photograph of the exposure of Wakai agglomerate near the Wakai village

Close up of Wakai Exotic Blocks - subangular boulders & pebbles of mafic volcanic rocks



Close up view of the agglomerate near Wakai village showing angular to subangular boulders and pebbles of mafic volcanic rocks.

Paleocene? Ispikan Formation



Paleocene? Ispikan Formation



Ispikan Sandstone with Cross Bedding



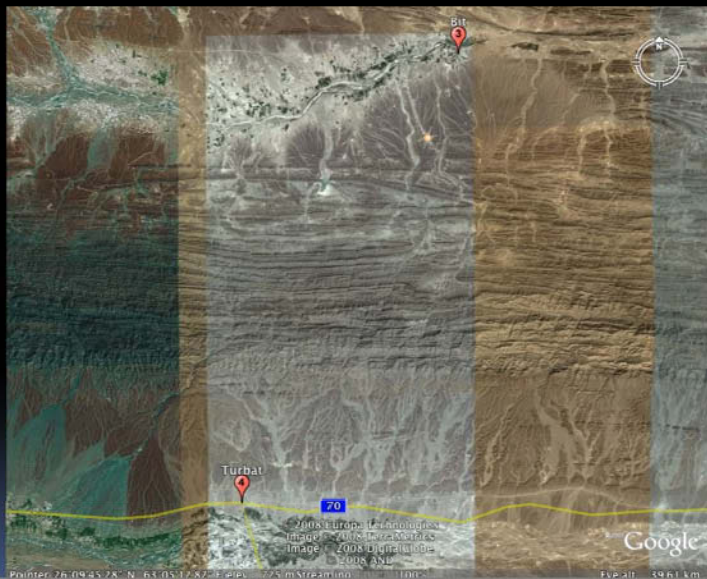
Well rounded pebble-boulder
conglomerate of the Ispikan Formation



Purple colored shale at the base
of the Ispikan Formation



Bit-Turbat Section



Oligocene-Miocene Panjgur Fm.



Turbidite Succession - Panjgur Fm. Bit-Turbat section



Field photograph of the thick-bedded sandstone-dominant succession at Bit-Turbat road section. Rhythmic alternations of sandstone and shale beds are characteristic of turbidite succession. Panjgoor Formation has turbidite successions which show deposition in submarine fan environments. Note second-order cyclicity within the succession.

Thin Bedded SS-SH Succession, Bit-Turbat section, Panjgur Fm.



Field photograph of the thin-bedded shale-dominant succession at Bit-Turbat road section northeast of the town of Turbat. Note lateral continuity of thin sandstone and shale beds.

Flute Casts - Panjgur Fm.



Field photograph of the flute marks at the base of a sandstone bed of the Panjgur Formation--commonly found in the turbidite successions.

Turbat-Pasni Rd. Section



Image © 2008 TerraMetrics
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© 2008 Europa Technologies
Image © 2008 DigitalGlobe

©2007 Google™

Pointer: 25°27'47.14" N 63°26'29.02" E elev 28 m Streaming 100%

Eye alt 158.18 km

Panjgur Fm., Pasni-Turbat Rd.Section, South of Pidarak



Field photograph of the thin-bedded shale-dominant succession at Pasni-Turbat road section south of Pidarak. Note lateral continuity of thin sandstone and shale beds.

Panjgur Fm. - South of Pidarak



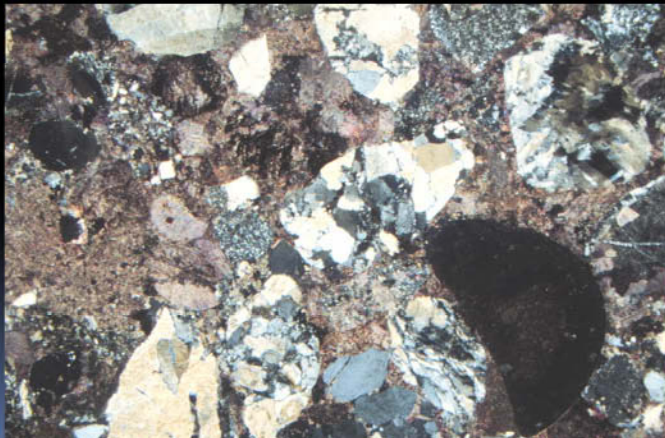
Field photograph of the thin-bedded shale-dominant succession at Pasni-Turbat road section south of Pidarak. Note lateral continuity of thin sandstone and shale beds.

Imbricated Sandstone Bed, Panjgur Fm.



PETROGRAPHY

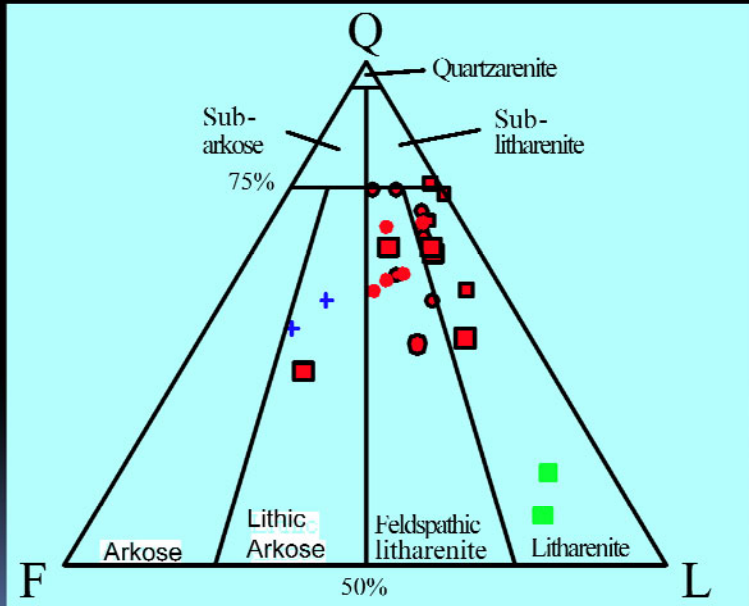
Provenance



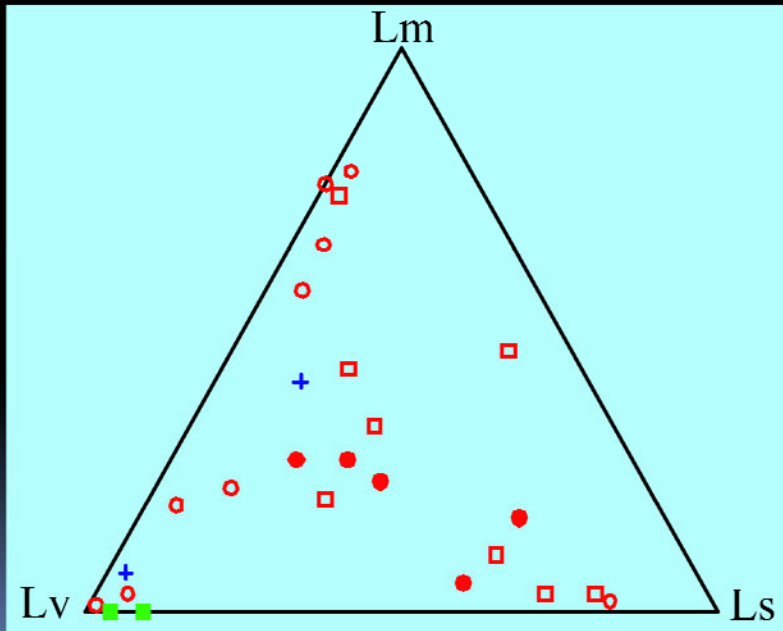
Sandstone Composition

Red = Panjgur Fm.
Blue = Ispikan Fm.
Green = Wakai

After Folk, 1980

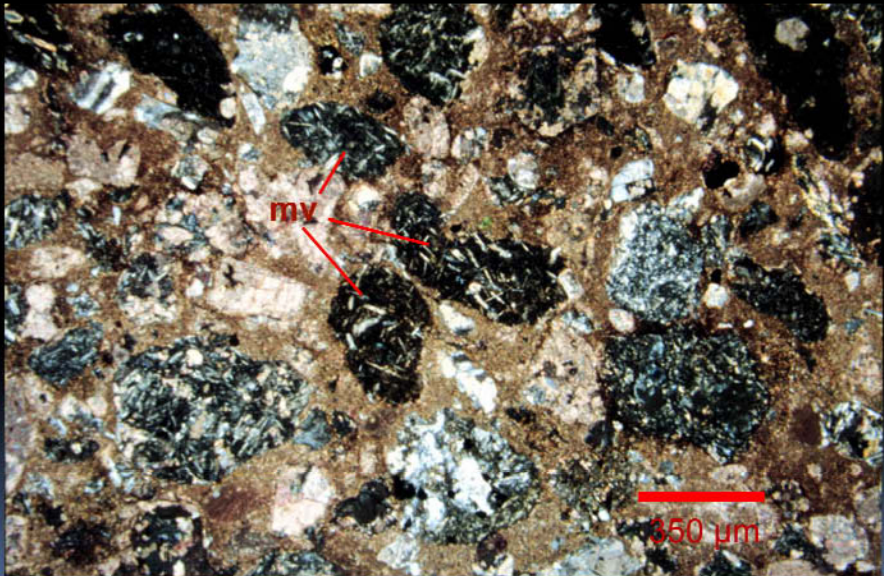


Lithic Fragment Composition



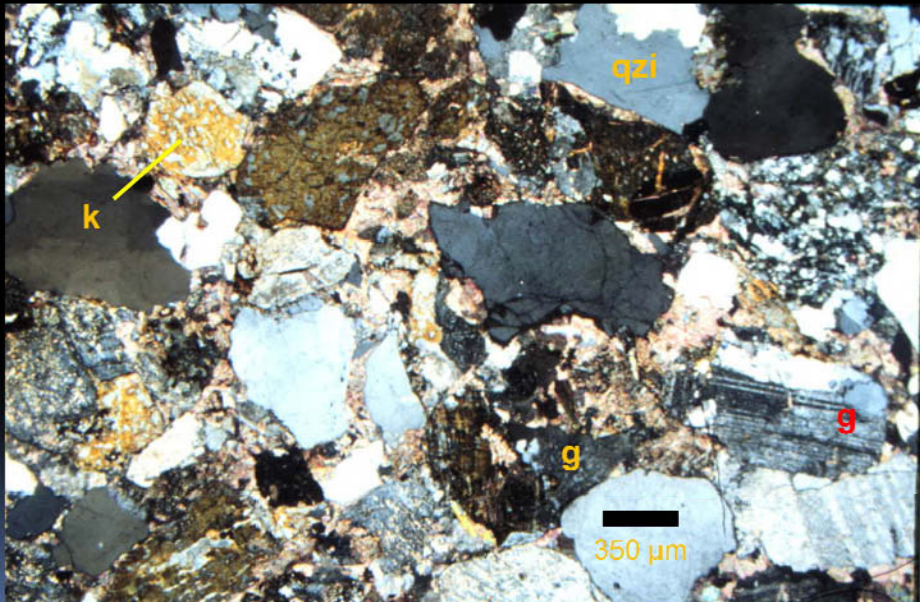
LmLvLs compositional diagram (after Dickinson and Suczek 1979) of sandstones of the Panjgur Formation, Ispikan Formation, and Wakai mélange showing a mixed igneous, sedimentary, and metamorphic provenance.. Symbols are same as in previous figure.

Wakai Sandstone



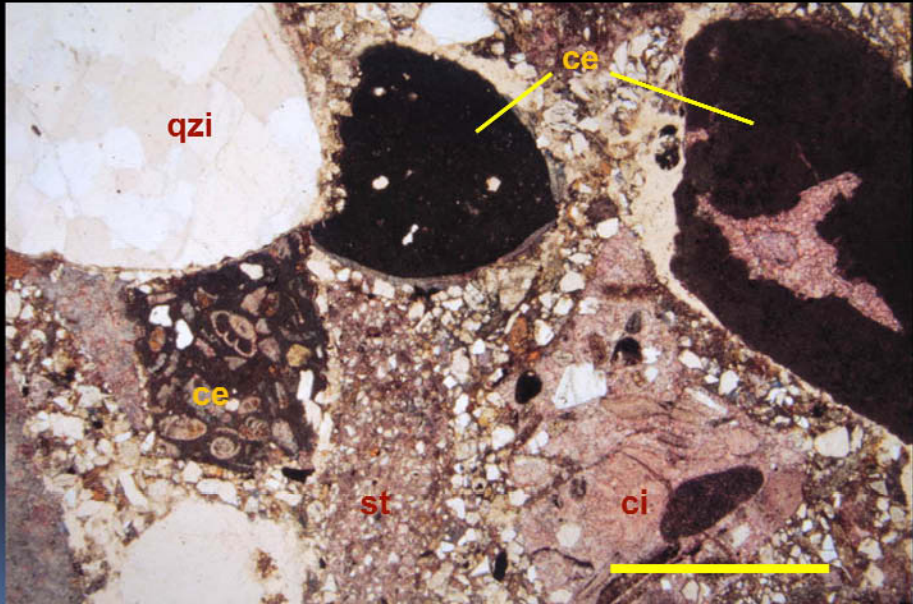
Photomicrograph of the volcaniclastic sandstone of the Wakai mélangé showing abundant mafic volcanic fragments within micritic cement; crossed polars.

Ispikan Fm.



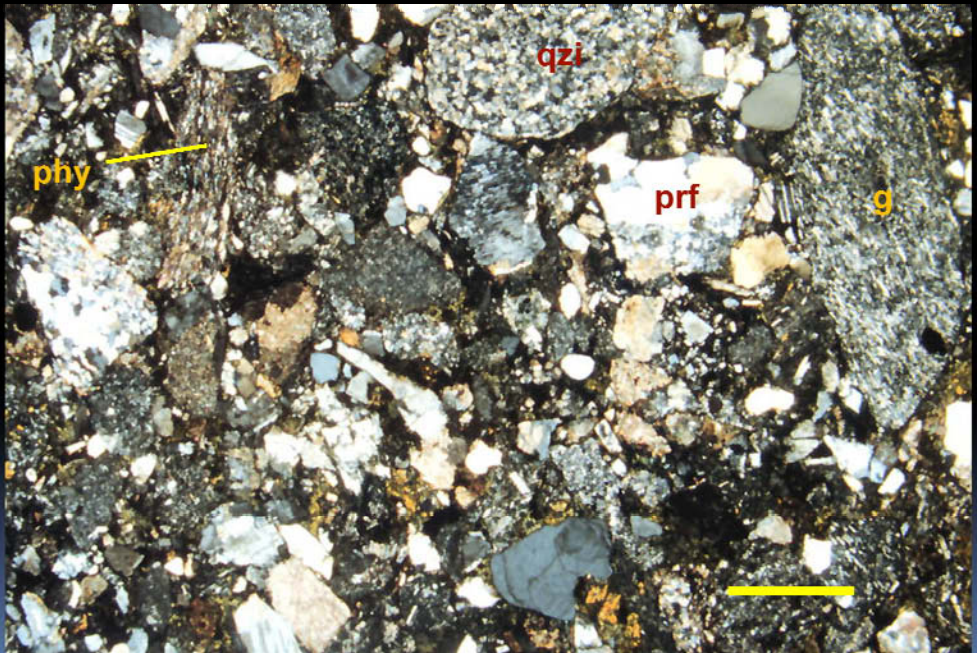
Photomicrograph of the sandstone of the Ispikan Formation showing granitic and metamorphic fragments. Note the presence of k-feldspar (stained yellow) within the granitic rock fragments; crossed polars.

Panjgur Fm. - Wakai Section



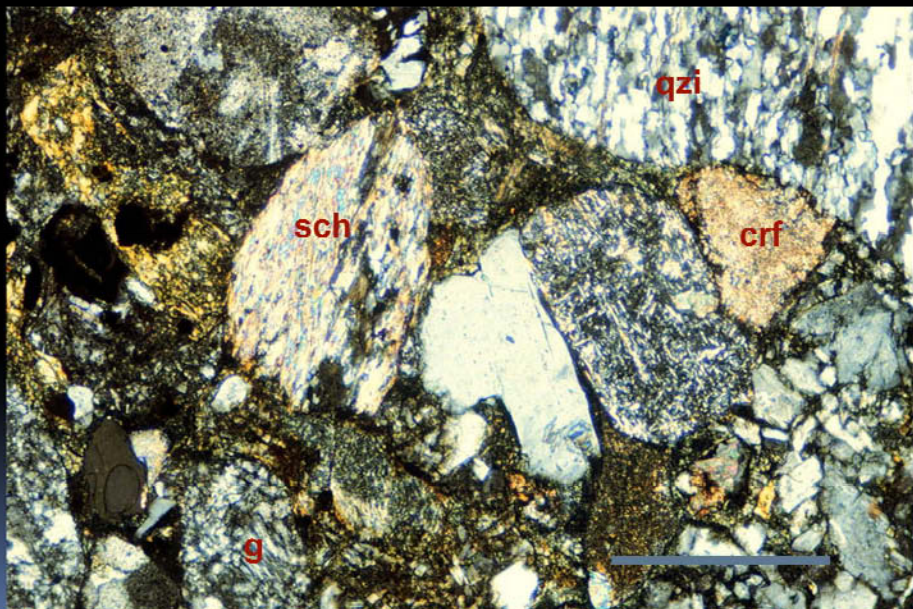
Panjgur Formation from Wakai section showing extrabasinal limestone (ce), some being fossiliferous containing pelagic foraminifera, siltstone (st), and quartzite fragments (qzi); crossed polars. Bar scale equals 250 μm in all photomicrographs unless otherwise stated

Panjgur Fm. - Wakai Section

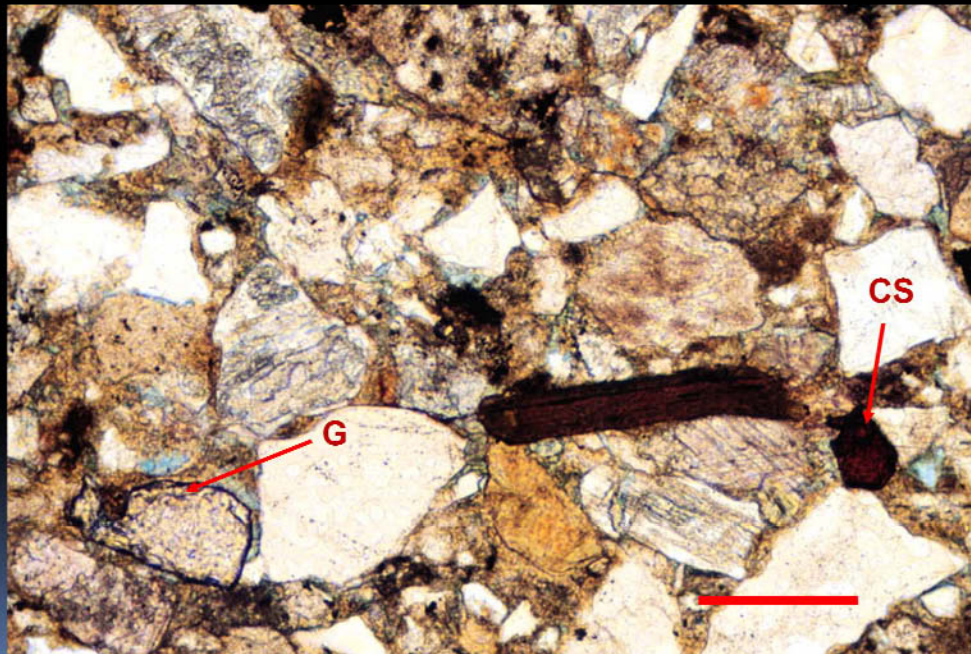


Photomicrograph of the sandstone of the Panjgur Formation from Wakai section showing various types of igneous and metamorphic rock fragments; crossed polars.

Panjgur Fm.- Wakai-Ispikan Section



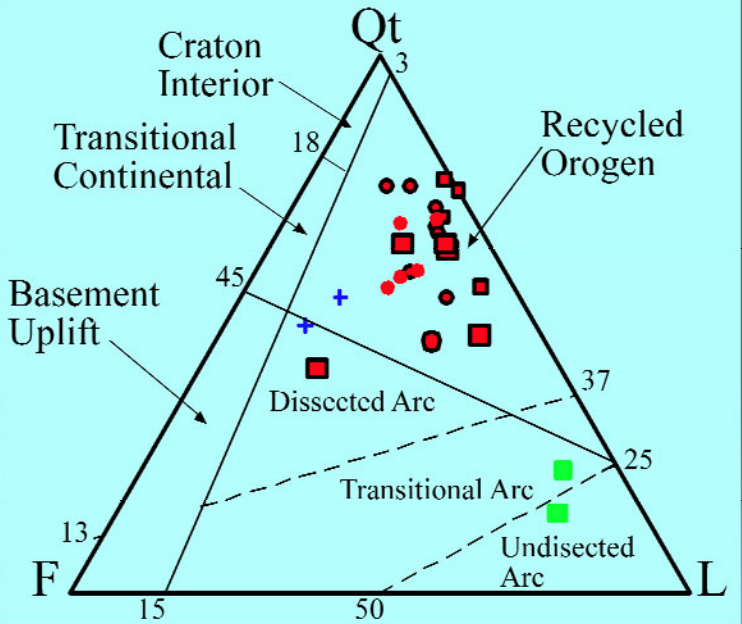
Panjgur Fm. - Pasni-Turbat Section



Photomicrograph of the sandstone of the Panjgur Formation from Pasni-Turbat road section showing various types of mineral and fossil fragments. Note grains of garnet (lower left corner), chrome spinal (lower right corner), and partial replacement of feldspar grain by calcite (left center); plane polarized light.

QtFL Tectonics Plot

Red = Panjgur Fm.
Blue = Ispikan Fm.
Green = Wakai



After Dickinson
& Suczek, 1979

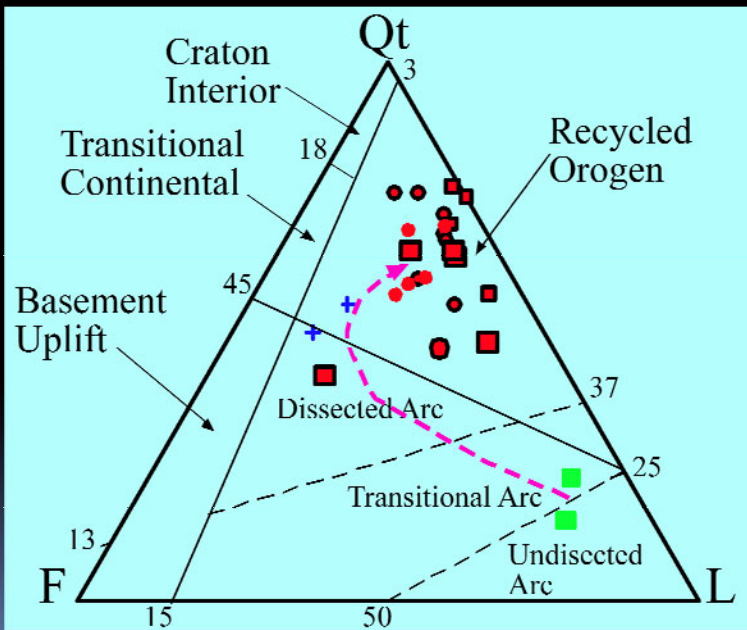
QFL compositional diagram (after Dickinson and Suczek 1979) of sandstones of the Panjgur Formation, Ispikan Formation, and Wakai mélangé. Most of the samples of the Panjgur Formation and Ispikan Formation plot in the field of recycled orogen, whereas, the two sandstone samples

of the Wakai mélangé plot in the fields of undissected and transitional arc. Symbols are same as in previous figures.

QtFL Tectonics Plot

Red = Panjgur Fm.
Blue = Ispikan Fm.
Green = Wakai

After Dickinson
& Suczek, 1979

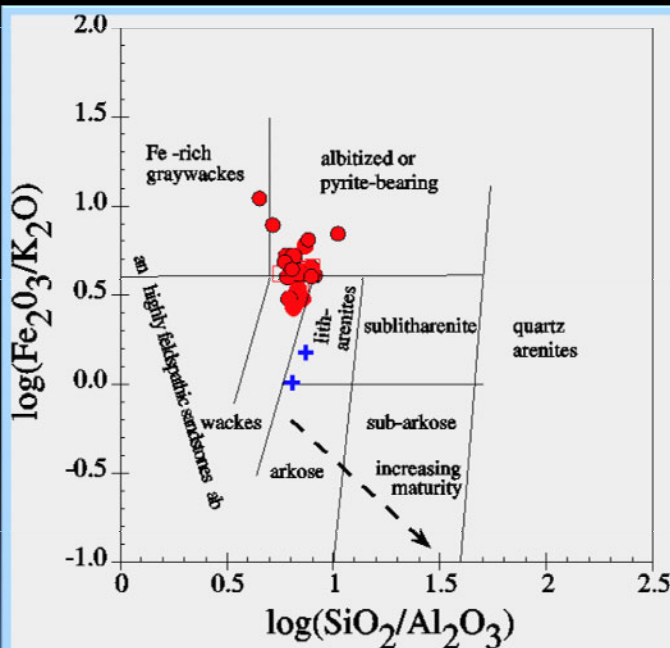


GEOCHEMISTRY

Provenance

Major Element Terrigenous Classification

Red = Panjgur Fm.
Blue = Ispikan Fm.

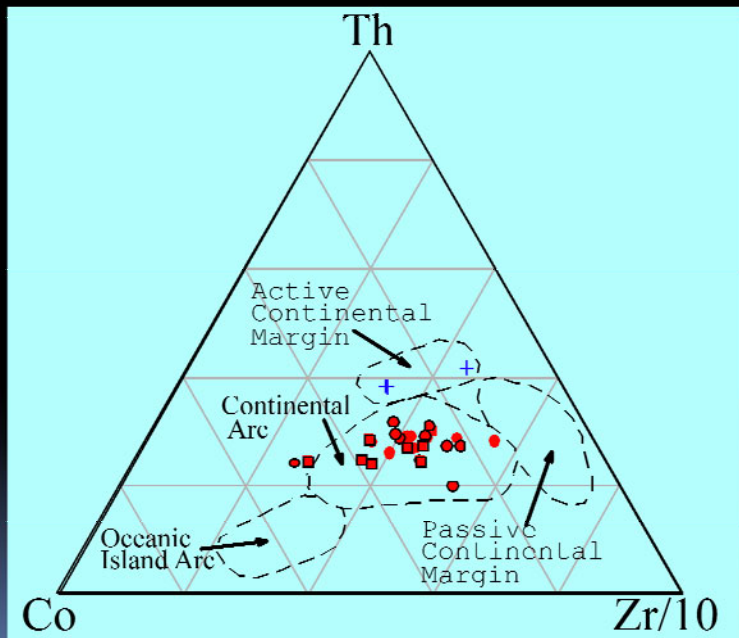


After Herron, 1988

Major-element classification of terrigenous sandstones reflecting sedimentary maturity (Herron 1988). Symbols the same as in previous figures.

Th-Co-Zr/10 compositional diagram

Red = Panjgur Fm.
Blue = Ispikan Fm.

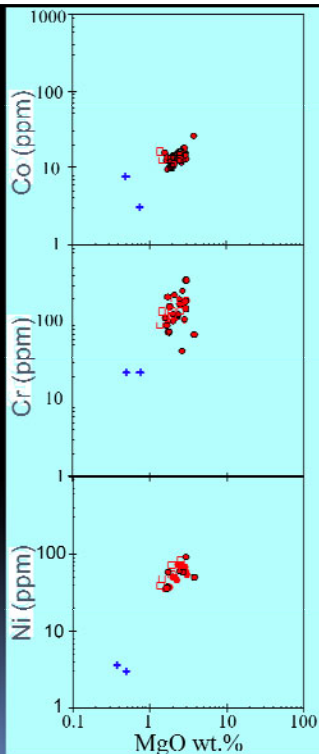


After Bhatia and
Crook, 1986

Th-Co-Zr/10 discrimination diagram for sandstones (Bhatia and Crook 1986). Symbols the same as in previous figures.

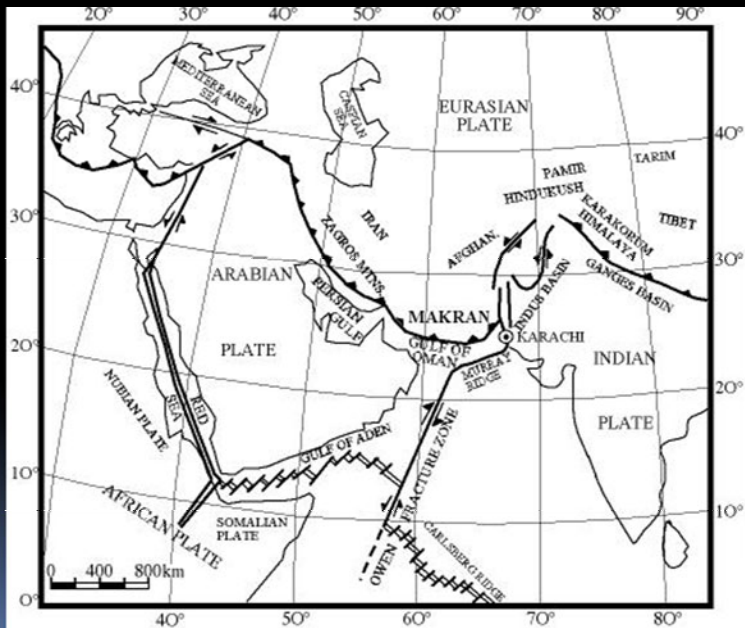
Evidence for Ultramafic Source

Red = Panjgur Fm.
Blue = Ispikan Fm.

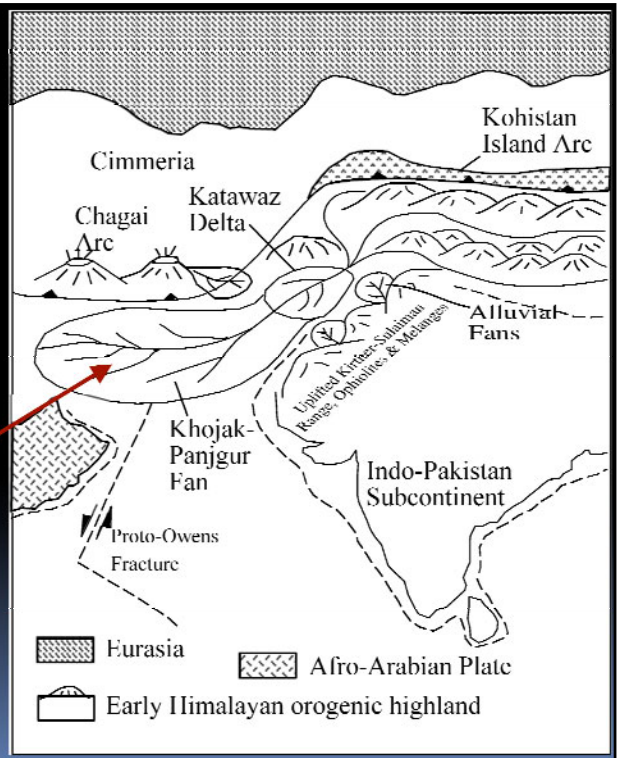
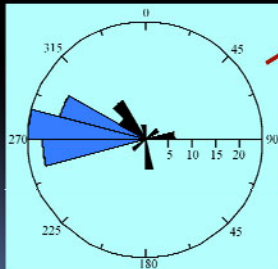


Log-log plots of Co, Cr, and Ni against MgO. High abundances of Co, Cr, and Ni are indicative of contributions from ultramafic sources. Symbols the same as in previous figures.

Tectonic Setting



Schematic diagram showing paleogeographic setting during deposition of the Panjgur sediments (modified after Qayyum et al., 2001)

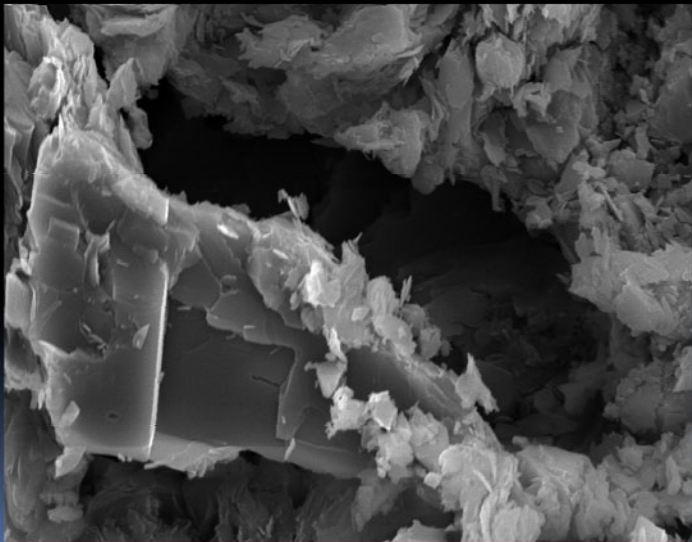


Schematic diagram (modified after Qayyum et al., 2001), showing paleogeographic setting of Indo-Pakistan subcontinent, Eurasia, and the Katawaz delta and Khojak-Panjgur submarine fan in the Katawaz Ocean.

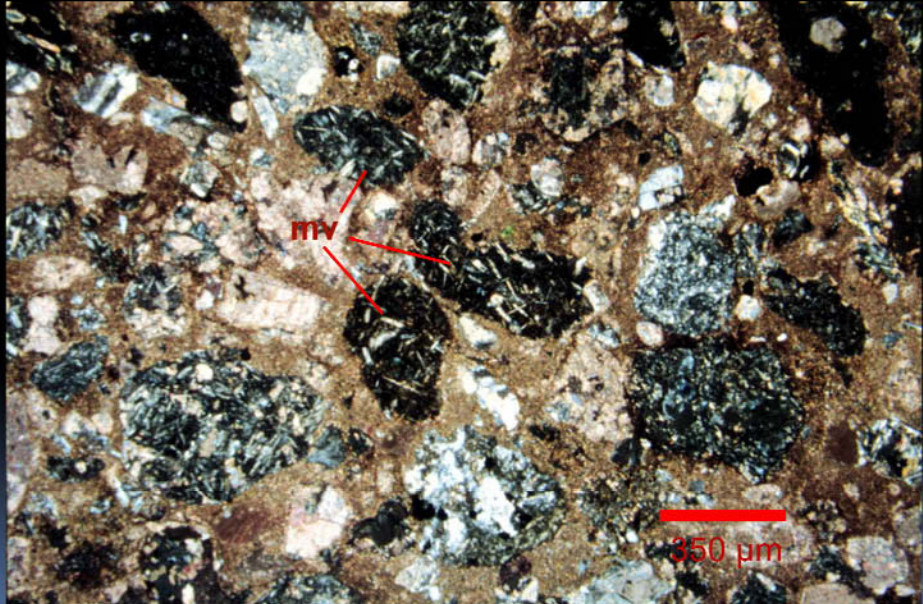
We support the model that the Panjgur and Ispikan detritus was transported from the Himalayan collisional orogen southward across strike and deposited as a turbidite system in the Katawaz Ocean. The initial southward transport was controlled by the Chaman-Ornach Nal transform fault system. In the Makran region the submarine fan depositional system turned westward, roughly parallel to the present active margin of the Makran accretionary wedge.

The Bela-Muslimbagh ophiolites and associated mélanges in the east and Chaghai-Raskoh volcanic arc to the west concurrently shed mafic to ultramafic detritus that is also preserved in the study area.

Diagenesis

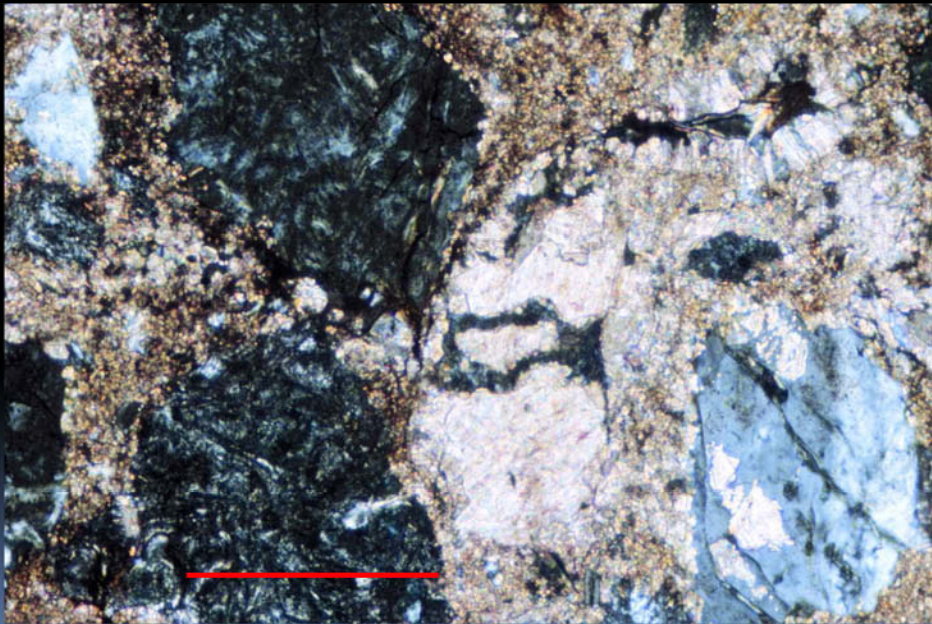


Wakai Exotic Blocks Sandstone



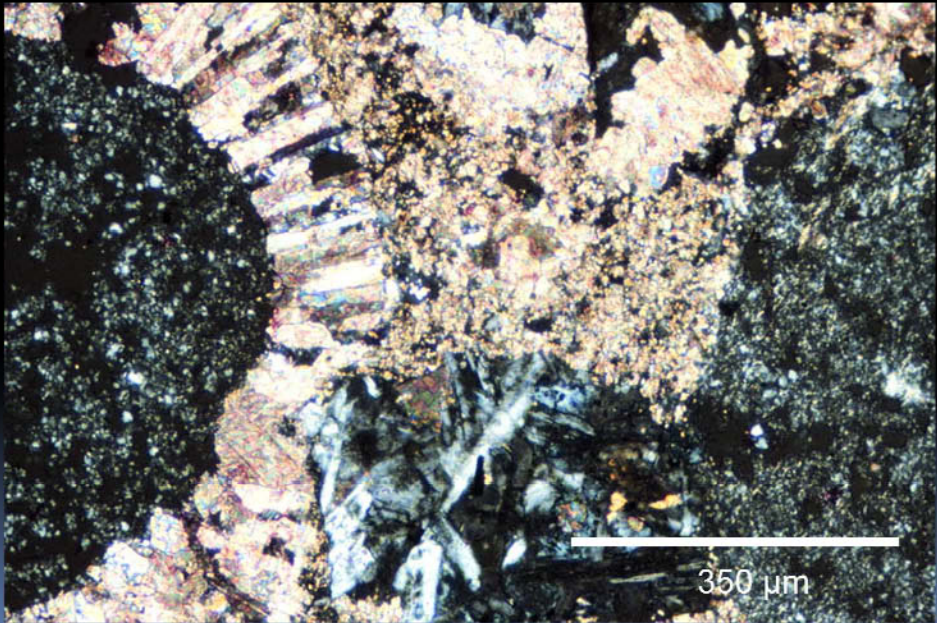
Photomicrograph of the volcaniclastic sandstone of the Wakai mélangé showing abundant mafic volcanic fragments within micritic cement; crossed polars.

Wakai Exotic Blocks Sandstone



Chloritized mafic volcanic rock fragments. Micritic calcite. Fe-poor calcite replacing grains.

Wakai Exotic Blocks Sandstone



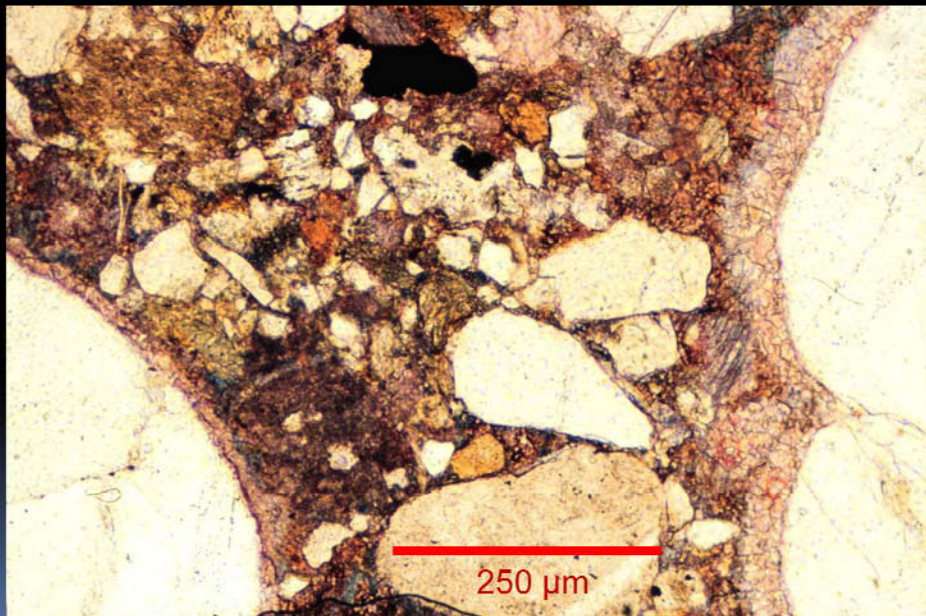
Photomicrograph of the volcaniclastic sandstone of the Wakai agglomerate showing growth of bladed rim of calcite around chert fragment and development of finely crystalline cement in the interstices; crossed polars.

Compaction, Ispikan Fm.

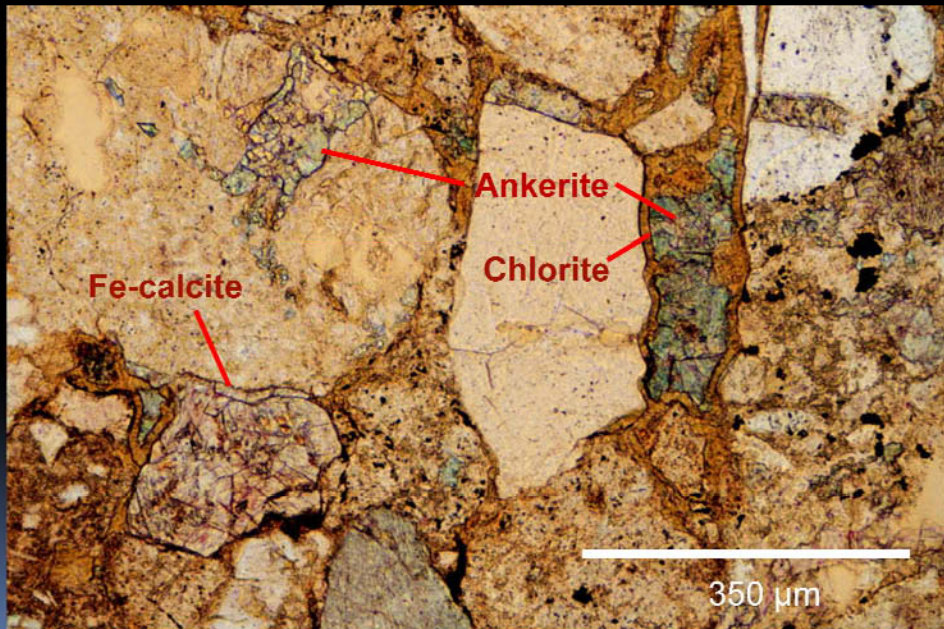


Fractured grains as a result of compaction. Fe-calcite fills fractures and displaces biotite along cleavage planes.

Early calcite, Panjgur Fm. - Wakai Section



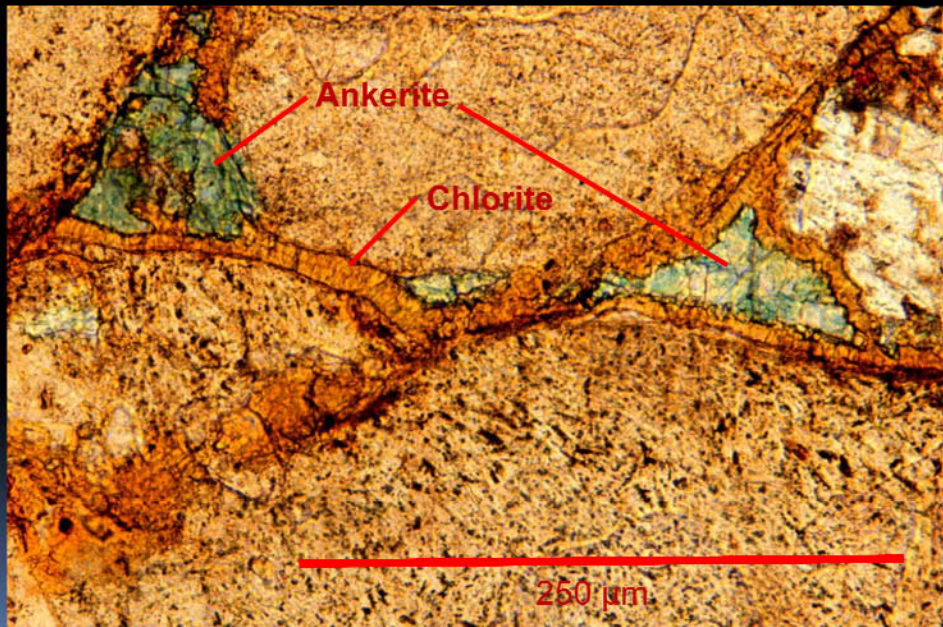
Panjgur Fm. - Wakai Section



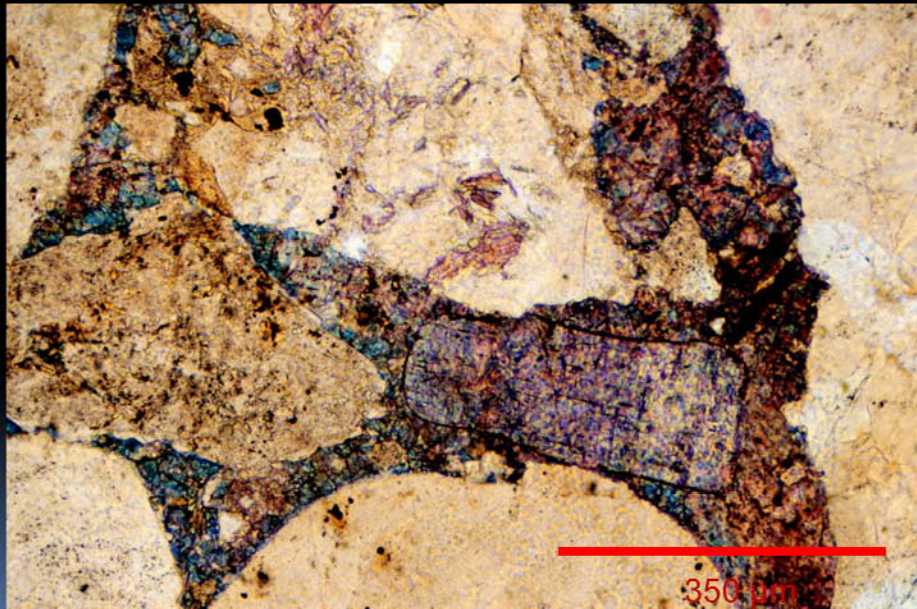
Fe-calcite & Chlorite – Panjgur Fm.



Panjgur Fm. - Wakai Section

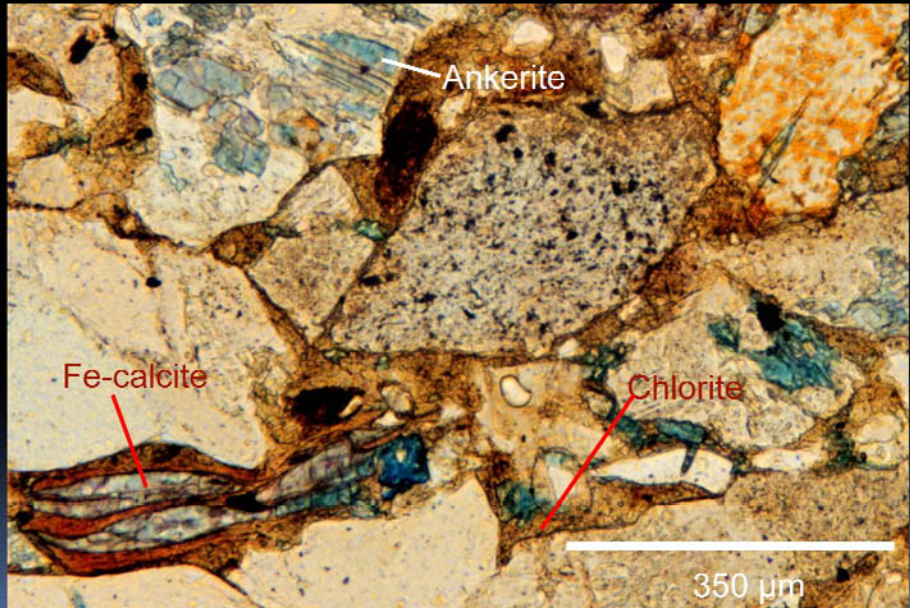


Panjgur Fm. - Pasni-Turbat Section



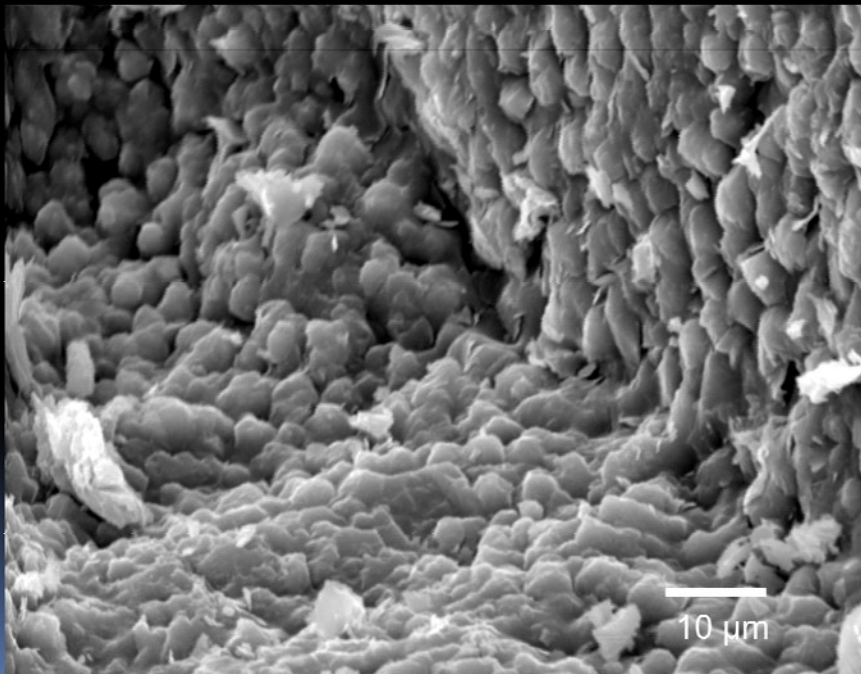
Calcitized and kaolinized feldspar, chert, and metamorphic r.f. in a calcite ferroan cement.

Panjgur Fm. - Pasni-Turbat Rd. Section

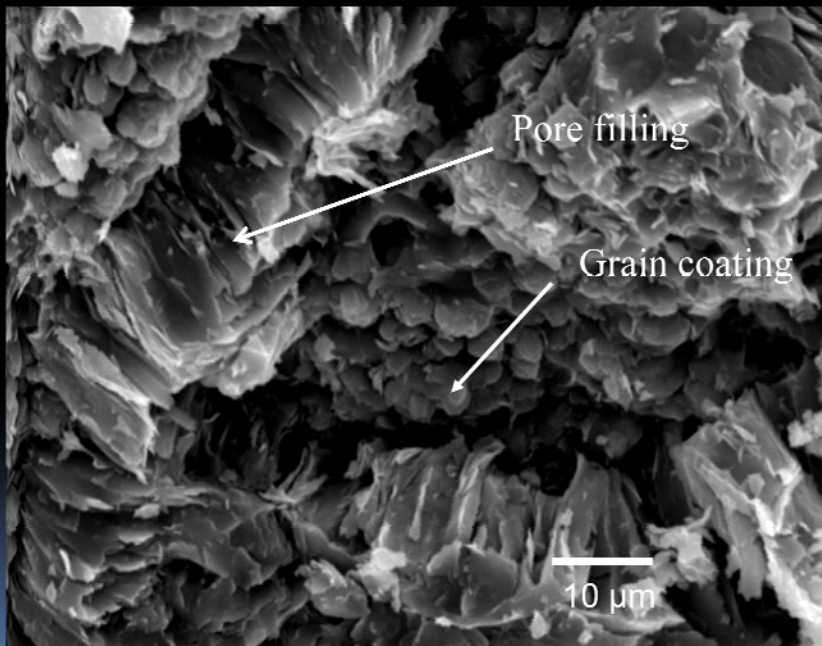


Displacive ferroan calcite (mauve stained) disrupting biotite grain and patchy calcite replacing plagioclase and orthoclase (yellow stained). Chlorite cement surrounds grains.

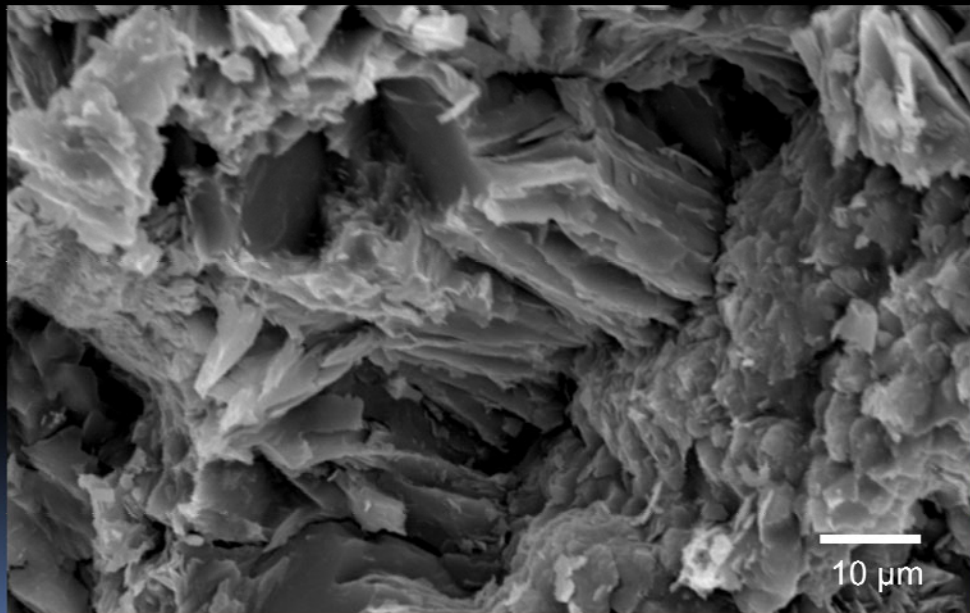
Grain coating chlorite - rounded by dissolution?



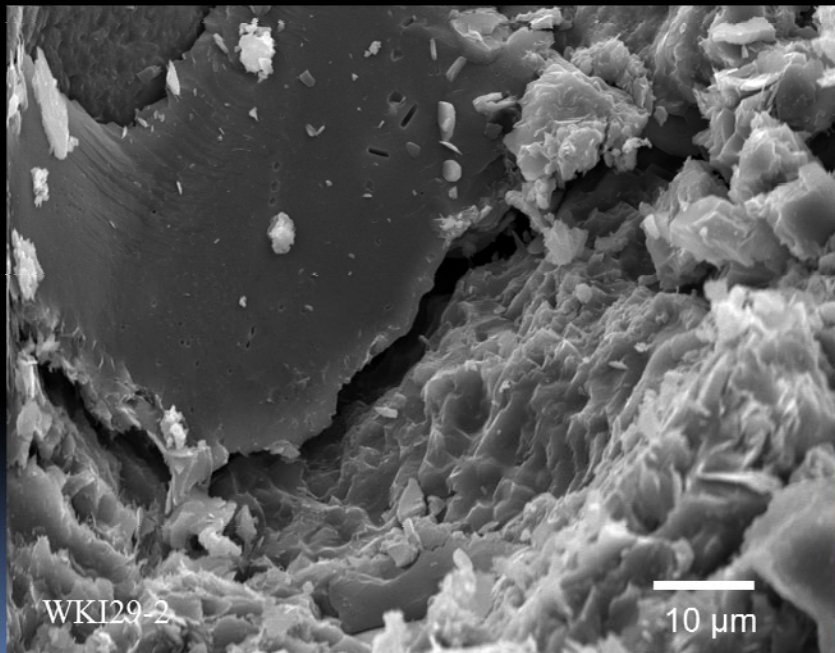
Grain coating & pore filling chlorite



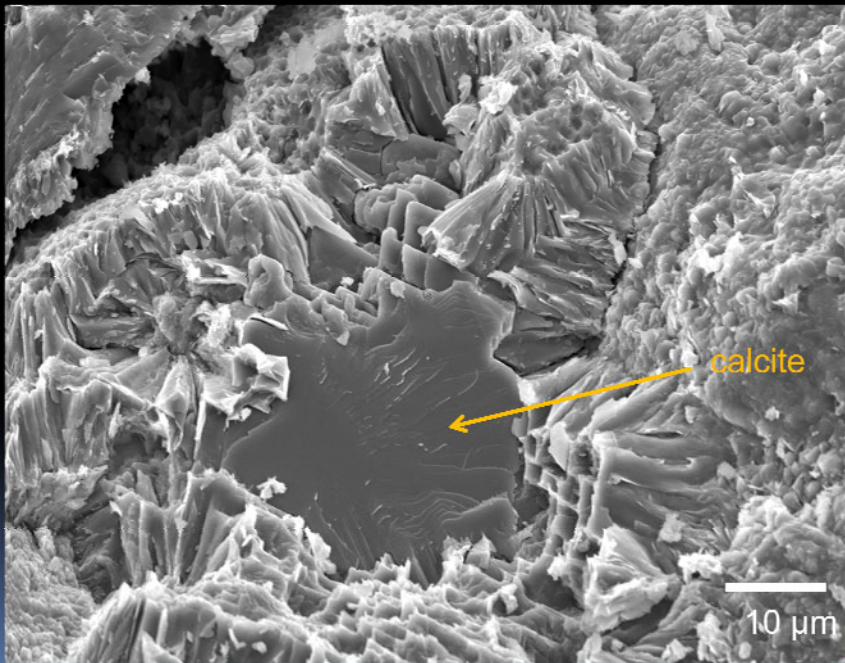
Chlorite growth



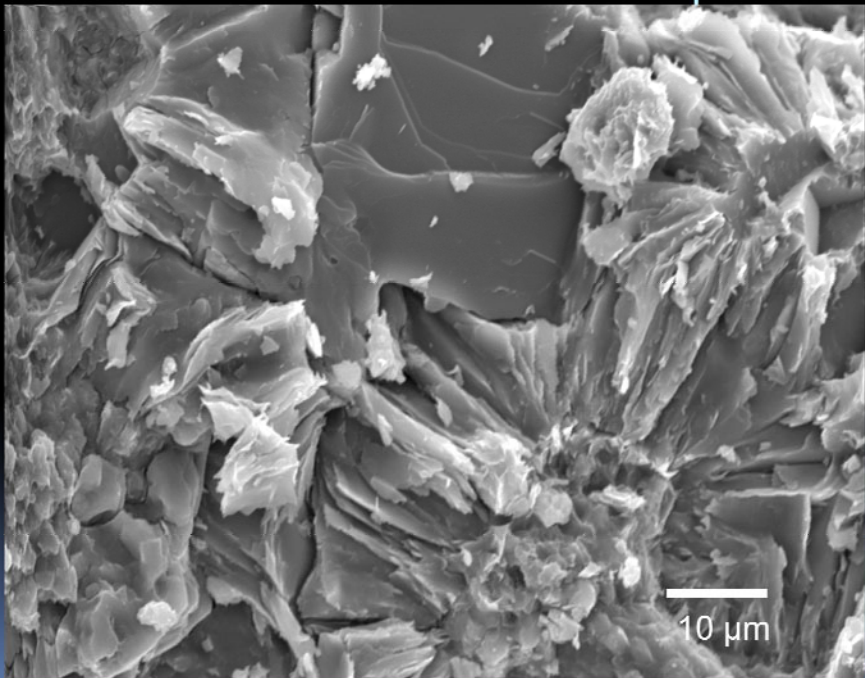
Calcite dissolution



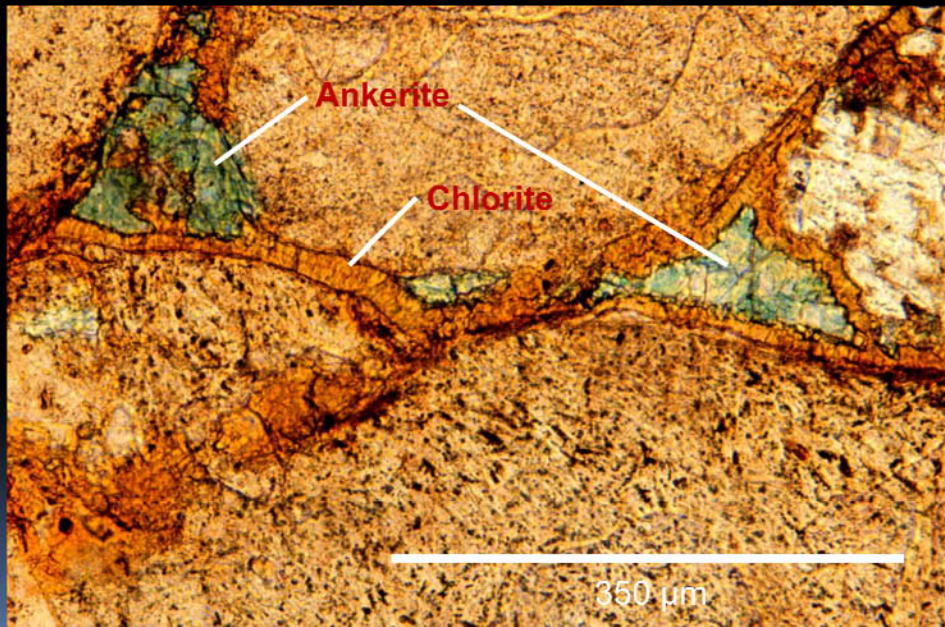
Grain coating & pore filling chlorite & calcite



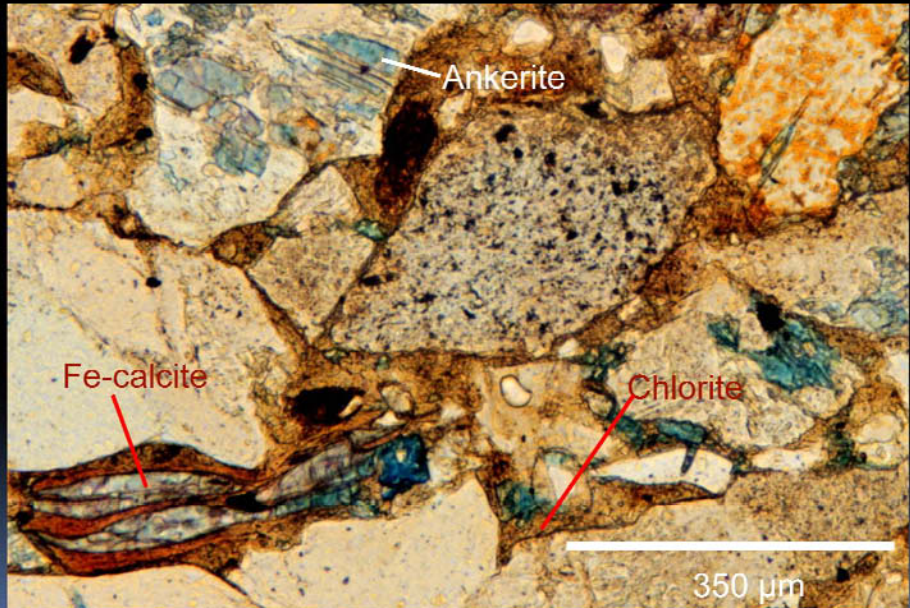
Calcite - Chlorite Relationships



Panjgur Fm. - Wakai Section

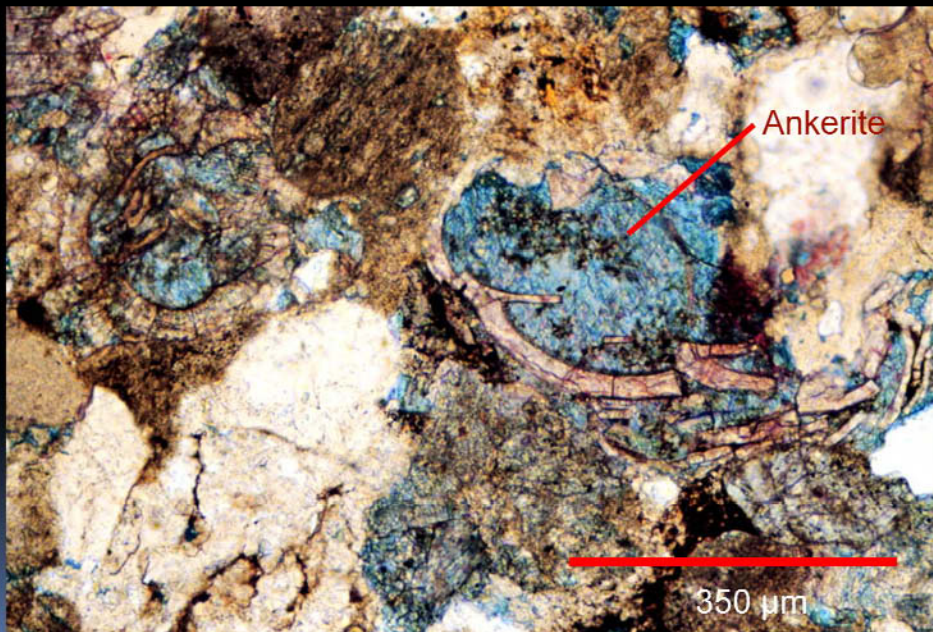


Ankerite filling secondary pore space



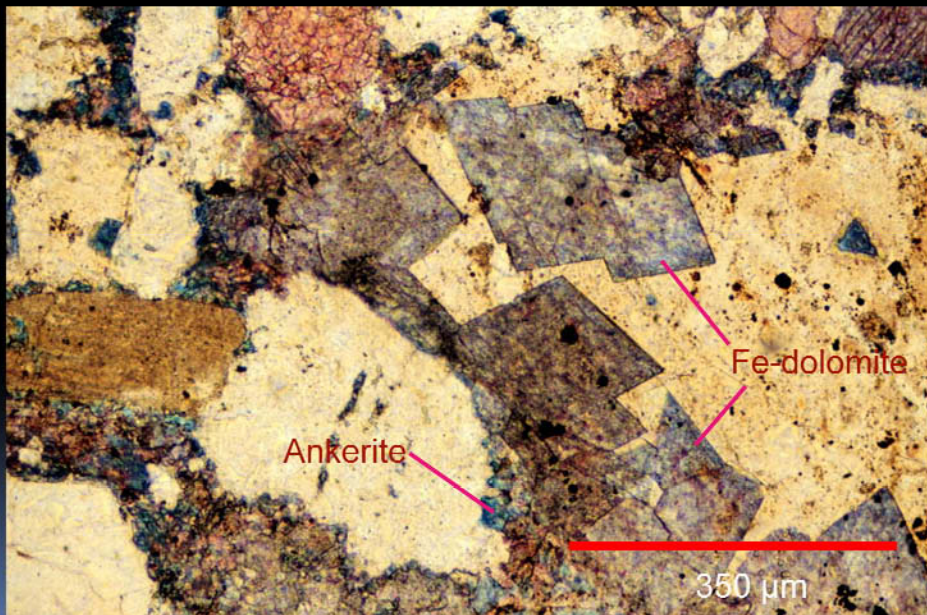
Displacive ferroan calcite (mauve stained) disrupting biotite grain and patchy calcite replacing plagioclase and orthoclase (yellow stained). Chlorite cement surrounds grains.

Panjgur Fm. - Pasni-Turbat Section



Secondary porosity filled by late stage ankerite.

Panjgur Fm. - Pasni-Turbat Section



Calcite ferroan (mauve stained) and ankerite (blue stained) replacing various r.f. (e.g, chert)

Conclusions (at the moment)

Sandstone composition of the Wakai exotic blocks, and the Ispikan and Panjgur Formations of the Makran belt indicates a transition from undissected arc to dissected arc to recycled orogen during Cretaceous to Miocene time.

Geochemical data support an active continental margin to continental arc tectonic setting.

Detritus was derived from the Himalayan orogenic belt and associated suture belts, ophiolite complexes, and volcanic arcs.

Conclusions (continued)

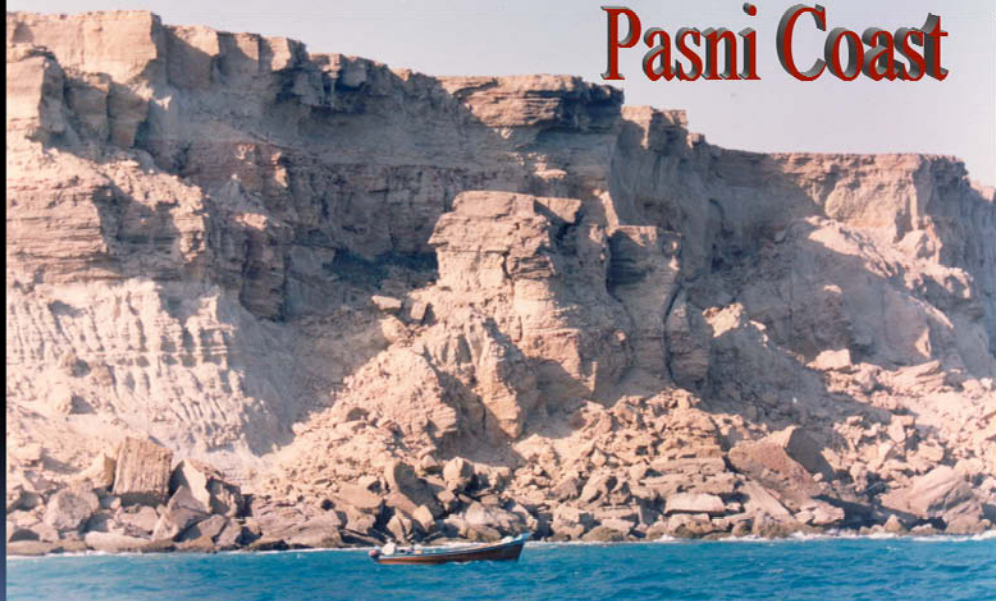
Early cementation (calcite &/or chlorite) retards compaction.

Wakai and Ispikan sandstones are dominated by early Fe-poor calcite that is replaced by a later ferroan calcite.

Diagenesis of the Oligocene-Miocene Panjgur Fm is complex.

- a) Minor compaction with formation of chlorite grain coats & early Fe-poor calcite.
- b) Fe-calcite precipitation replacing grains, Fe-poor calcite (& chlorite?)
- c) Carbonate dissolution & chlorite grain coating dissolution, precipitation of pore filling chlorite.
- d) Dissolution of feldspars
- e) Precipitation of ankerite filling secondary pore spaces
- f) Precipitation of Fe-dolomite

Pasni Coast



Field photos taken by Akhtar Kassi

The Ispikan and Panjgur Formations of the Makran accretionary belt are composed of high proportions of quartz and metamorphic, igneous, and sedimentary rock fragments.

- 1) The QtFL plot suggests a dissected arc to recycled orogen for these sandstones.
- 2) The rock fragments and associated heavy minerals, like serpentinite and chrome spinel, suggest that the detritus was derived from the Himalayan orogenic belt and associated suture belts, ophiolite mélanges, and volcanic arcs.
- 3) Geochemical data support an active continental margin to continental arc tectonic setting for these sandstones with the Panjgur Fm. getting contributions from the ophiolite mélanges. This contribution is minor or absent in the Ispikan Fm.
- 4) Sandstone of the Wakai mélange is very rich in mafic volcanic fragments, which were derived from a nearby volcanic source. Its association with sheared mafic volcanic rocks, purple colored shales, cherts, marbles, and pelagic limestones suggest that they were possibly derived from the ophiolitic mélanges obducted due to the subduction of oceanic crust of the Gulf of Oman,
- 5) We support the model that the Panjgur and Ispikan detritus was transported from the Himalayan collisional orogen southward across strike and deposited as a delta-submarine-fan system in the Katawaz Ocean. The initial southward transport was controlled by the Chaman-Ornach Nal transform fault system. In the Makran region the submarine fan depositional system turned westward, roughly parallel to the present active margin of the Makran accretionary wedge.
- 6) The Bela-Muslimbagh ophiolites and associated mélanges in the east and Chaghai-Raskoh volcanic arc to the west concurrently shed mafic to ultramafic detritus that is also preserved in the study area.

Selected References

- Bakr, M.A., and R.O. Jackson, 1964, Geological map of Pakistan: Survey of Pakistan, Rawalpindi, Pakistan: one sheet 91x111 cm., scale 1:2,000,000.
- Bhatia, M.R., and K.A.W. Crook, 1986, Trace element characteristics of graywackes and tectonic setting discrimination of sedimentary basins: *Contributions to Mineralogy and Petrology*, v. 92/2, p. 181-193.
- Dickinson, W.R., and C.A. Suczek, 1979, Plate tectonics and sandstone compositions: *AAPG Bulletin*, v. 63/12, p. 2164-2182.
- Folk, R.L., 1980, *Petrology of sedimentary rocks*, 2nd edition: Hemphill Publishing Company, Austin, Texas, 184 p.
- Herron, M.M., 1988, Geochemical classification of terrigenous sands and shales from core or log data: *Journal of Sedimentary Petrology*, v. 58/5, p. 820-829.
- Qayyum, M., A.R. Niem, and R.D. Lawrence, 2001, Detrital modes and provenance of the Paleogene Khojak Formation in Pakistan; implications for early Himalayan Orogeny and unroofing: *GSA Bulletin*, v. 113/3, p. 320-332.