eas characterized by E-W to WNW-ESE structural trends show declinations rotated clockwise. Declinations show a correlation with the structural trend for both HT and LT components, but in the case of the LT component the magnitude of the declinations deviation is smaller. Results from the sandstones confirm the presented outcomes and additionally prove the heterochronic age of the deformations that differ between the marginal and the internal zone of the fold–and–thrust belt.

The presented declination data support only local oroclinal bending which give rise to the strike deviations in the thrust-belt. In the Ardennes clockwise rotations of the thrust occurred only within narrow transpressive zones, active during the propagation of the thrusts. It is also suggested that the long segment of WNW-ESE trending thrust-belt, that includes the Massive Artois, represents the oblique transfer zone between the Ardeno-Rhenish and SW England frontal belts.

Mechanics of Large-Scale Sand Injection – Understanding the Hamsun Giant Sand Injectite Complex

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Sandstone intrusions (injectites) are intriguing features as, despite their widespread occurrence, their origin is poorly constrained. The lack of process understanding poses a challenge to anyone dealing with post-depositional sediment remobilization. The formation of large-scale sand injectites has been attributed to various factors and processes such as: overpressure build-up, fracture propagation, fluidization, etc. Overpressure build-up can be caused by a variety of mechanisms such as disequilibrium compaction, loading by mass transport deposits, earthquakes, bolide impacts, or injection of fluids external to the sand body, such as, for example, hydrocarbons. Fractures start to propagate when pore-fluid pressure in a sand body exceeds the vertical or horizontal stress and the tensile strength of the host rock. Pressure-differential forces sediments to flow and fill fractures in the host rock. Depending on pressure conditions in the source bed and the seal and on the rheological properties of the host rock, sand injectites may form a range of geometries.

Clastic injectites occurring in the form of sills or dykes have been described for many decades. The size of clastic intrusions varies on a scale from sub centimetre to hundreds of metres. Recently, they have been recognized not only in outcrops but also on seismic data. A spectacular example is the Hamsun giant sand injectite complex that is located in the Paleogene of the North Sea. This complex is believed to be world's first sand injectite that was deliberately (and successfully) drilled by Marathon Oil UK as a hydrocarbon prospect, adding several tens of millions of barrels of oil to their Alvheim development. The Hamsun complex is sourced from the Hermod sand which occurs in Sele Formation and is believed to be of early Eocene age. The injectite complex was investigated by means of multi-volume-based 3D seismic interpretation and visualization in order to gain detailed characterization of the complex body. Overall shape of the body was analyzed, including its thicknesses, angles, depths, heights and relation to faults. Borehole core from two locations along the injectite were examined and constitute the ground truthing of the 'remote sensing' 3D seismic datasets. The investigations enabled drawing some conclusions about the Hamsun complex, like for example multi – phase injection.

Sand injectites are currently the subject of a concerted research effort at the University of Aberdeen, drawing on data from key outcrop analogues and selected sand injectite oil fields to catalogue the range of injectite styles, grain size variations, geometries and sizes, in order to establish genetic models and assist in reservoir modelling of sand injectite oil fields.

Record of Motion Along the Red River Fault Zone in Provenence Studies, Northern Vietnam

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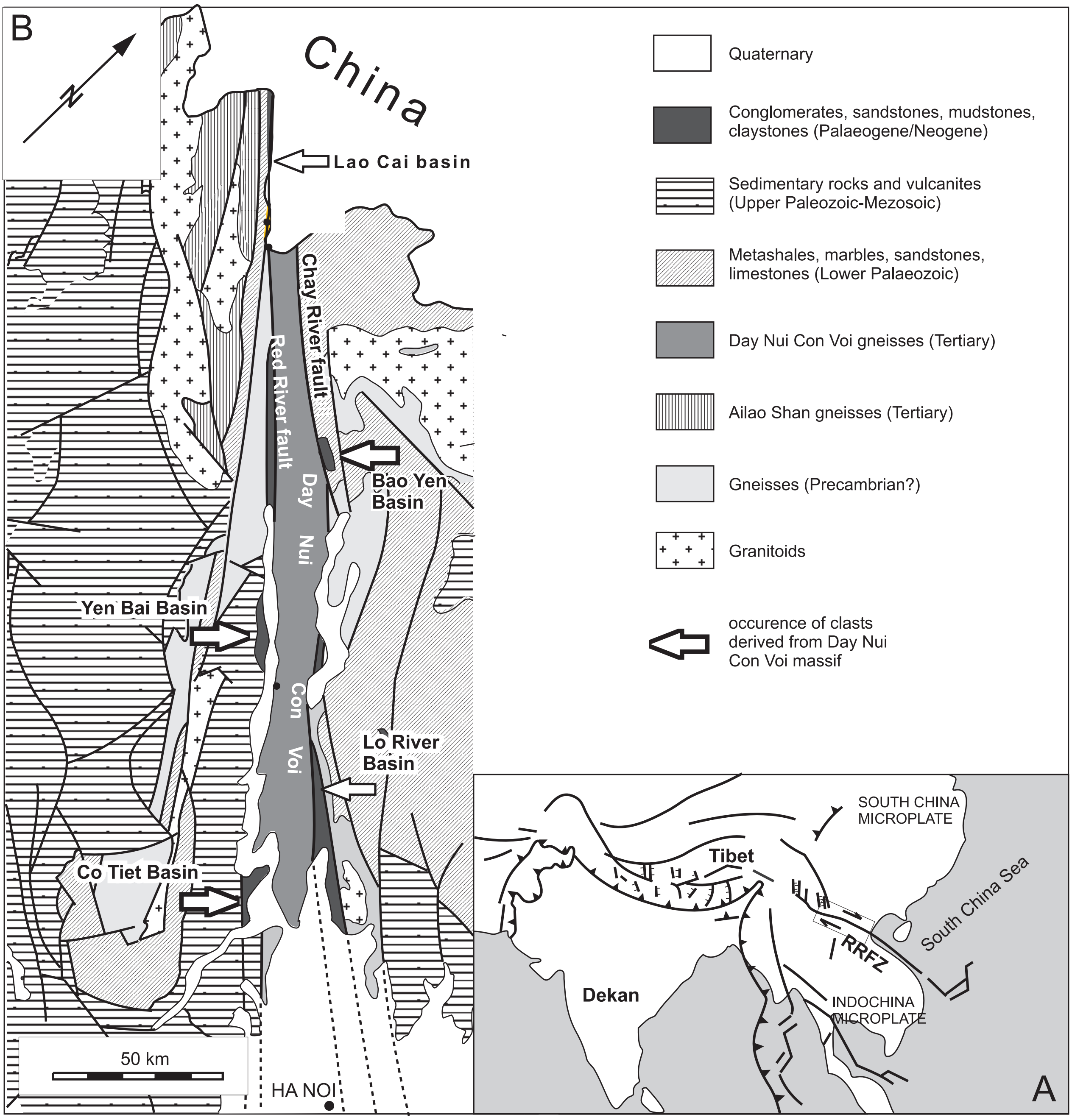
Provenance studies and, clast analysis in particular, are a valuable source of information on timing of uplift and denudation in source area. These studies may also document motion of a source area for basins related to strike-slip faulting. In this paper we present first results of clasts analysis from sedimentary basins adjoining the Red River Fault Zone (RRFZ) in Northern Vietnam.



■ **Fig. 1.** A. Location of studied region in SE Asia (rectangular). B. Geological sketch map of NW Vietnam showing location of the Paleogene/Neogene basins along the RRFZ.

The Red River Fault Zone (RRFZ) is a large strike-slip zone that separates Indochina and South China microplates. In the northern Vietnam (Fig. 1), the NW-SE trending RRFZ comprises two main faults: Red River Fault and Chay River Fault separated by up to about 25 km wide metamorphic Day Nui Con Voi massif (DNCV). The Red River Fault bounds the DNCV to the SW whereas Chay River Fault to the NE. Origin and uplift of this massif, formed by amphibolite facies paragneisses with minor contributions of mica schists, marbles and amphibolites, were related to left lateral movement along the RRFZ (Leloup et al., 2001 and references therein). However, dating of motion and estimation of amount of shifting along the RRFZ as well as time of exhumation are subjects of debate.

In the northern Vietnam, gneisses with bodies of amfibolite and metasedimentary rocks adjoin the RRFZ to the SW. Metasedimentary rocks dominate to the NE of the RRFZ. Close to the northern part of the RRFZ granitoid massifs are also present.

A few small sedimentary basins occur along the discussed faults. Their origin was probably connected to the tectonic activity of the RRFZ. (Leloup et al., 2001, Wysocka, Świerczewska 2002). The basins are filled with clastic Paleogene/Neogene strata representing fluvial and lacustrine depositional environments. The strata are characterised by numerous local facies changes.

Our studies were focused on two basins associated with the Chay River Fault and three basins associated with the Red River fault. The composition of the clast assemblages shows strong variability both in particular basins and between the basins. In all studied basins, the local source areas located outside of the DNCV are clearly marked. Clasts derived from the DNCV are recognized only in a few sites. The occurrence of these clasts in the basins associated with the Chay River fault show distinct differentiation. The clasts of the DNCV gneisses are observed in two exposures of deformed conglomerates in the Bao Yen Basin. The gneiss clasts were not observed in the second basin.

Along the Red River fault, in the Lao Cai Basin, only single clasts of gneisses were observed. The vast majority of the clasts are formed of granitoid clasts derived from Ailao Shan massif. It is not clear if the gneisess are derived from the DNCV. Further SE, in the Yen Bai Basin, the clasts of gneisses occur in undeformed conglomerates what suggest post-motion age of the conglomerates. In the Co Tiet Basin, clasts of DNCV gneisses occur in deformed, probably Miocene, strata. Like as the gneiss clasts, detrital garnets are common only in some samples of heavy minerals separated from Paleogen/Neogene sandstones of studied basins. Composition of these detrital garnets points to differentiation of metamorphic source area: from amphibolite to greenschists facies.

Presented results show that only for small portion of the fill of the basins, the high metamorphic DNCV was a source area. Poor dating of the sediments filling basins (palyonological data only) does not allow to precise stratigraphic position of strata containing clasts derived from the DNCV. Basing on degree of deformation of sampled strata it seams that the relationship between sedimentation of gneisses-bearing strata and deformation related to RRFZ activity is different for particular basins. Only in vicinity of Bao Yen and Cot Tiet basins uplift and exhumation of the DNCV was coeval or pre-dated deformation recorded in the sedimentary rocks. For these basins the offset along the RRFZ up to 200 km cannot be excluded.

References

LELOUP P.H., ARNAUD N., LACASSIN R., KIENAST J-R., HARRISON T.M., PHAN TRONG T.T., REPLUMAZ A. and TAPPONNIER P., 2001. New constraints on the structure, thermochronology, and timing of the Ailao Shan-red River shear zone, SE Asian. *Journal of Geophysical Researches*, 106: 6683-6732.

WYSOCKA A. and ŚWIERCZEWSKA A., 2003. Alluvial deposits from the strike-slip fault Lo River Basin (Oligocene/Miocene), Red River Fault Zone, north-western Vietnam. *Journal of Asian Earth Sciences*, 21: 1097-1112.

Structural Analysis and Paleostress Reconstruction of the Spišská Magura and Podhale Region

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The area of Spišská Magura and Podhale region is composed mostly of Mesozoic and Paleogene sequences. The most measurements were done in the Paleogene sediments.

In the study area we distinguished ten deformation stages connected with 1) E-W compression generated in strike-slip stress regime (?Paleocene), 2) NW-SE compression and perpendicular (NE-SW) tension generated in compressive strike– slip regime (Egerian–Eggenburgian), 3) NNW-SSE extension generated in pure extensive tectonic regime (Eggenburgian – Ottnangian), 4) NE-SW extension generated in pure extensive stress regime (Ottnangian–Karpatian), 5) NW-SE extension generated in pure extensive stress regime (Karpatian), 6) NW-SE compression activated in pure compressive stress regime (Badenian), 7) NNW-SSE compression generated in pure compressive stress regime (Sarmatian–Pannonian), 8) NE-SW compression activated in compressive strike-slip stress regime (?Pannonian), 9) NW-SE extension activated in pure extensive stress regime (?Pontian–Pliocene), 10) ENE-WSW extension generated in pure extensive stress regime (?Pliocene–Quaternary).

These ten deformation stages we divided in two groups.

The first group contains structures that were rotated to their recent position depending on uplift of the crystalline core of the High Tatras Mts. that started in Upper Miocene, according to FT dates from apatites (Kráľ 1977, Kováč et al. 1994, Struzik et al. 2003). This group contains the first six deformation stages originated from ?Paleocene up to the Badenian period.

The second group contains last four deformation stages that are the youngest structures originated after tilting of the High Tatras Mts. from ?Sarmatian up to the Quaternary period.

References

HÓK J., BIELIK M., KOVÁČ P. and ŠUJAN M. 2000. Neotektonický charakter Slovenska. *Mineralia Slovaca*, 32, 459-470.

JANOČKO J., GROSS P., POLÁK M., POTFAJ M., JACKO Ml.S., RAKÚS M., HALOUZKA R., JETEL J., PETRO Ľ., KUBEŠ P., BUČEK S., KÖHLER E., SIRÁŇOVÁ Z., ZLINSKÁ A., HALASOVÁ E., HAMRŠMÍD B., KAROLI S., ŽEC B., FEJDIOVÁ O., MILIČKA J., BOOROVÁ D. and ŽECOVÁ K.,