Final report VISTA 2011

Project title

Project director:	Andersen, Torgeir B. PGP, UiO
Post-doc/ scholar:	Souche, Alban
Project duration:	01.03.09 – 29.02.12
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Project number:	prosjekt 6255

1. **Popular project summary**

The temperature in a sedimentary basin is an important parameter for the exploration of natural resources such as petroleum and ore deposits, or for the use of geothermal energy. These temperatures can be predicted using numerical simulations but require a good knowledge of the geological system and a correct identification of the thermal processes within the crust. Two major heat sources are usually considered; the internal heat from the inner Earth; and the radioactive heat production from upper crustal rocks. However, depending on the geological setting, additional heat sources and thermal processes may bring complexity to the thermal structure of the system. This project documents and quantifies the amount of heat generated by rock deformation when two crustal blocks are displaced along a large shear zone (velocities ~3 cm/yr, offset ~100 km). This process may contribute to the heating and fluid circulation in sediments particularly in the vicinity of the shear zone. The Devonian continental basins in western Norway were used as a field analogue for the investigation. Sandstones and conglomerates dominate these continental deposits. They accumulated in the hanging-wall of one of the world´s largest extensional shear zones known as the Nordfjord-Sogn Detachment. Determination of the peak-temperatures of the sediments using Raman spectroscopy on organic carbon, show a characteristic increase close to the detachment. The numerical modeling presented in this study demonstrate that the deformation of rocks within the detachment was accompanied with a significant thermal feedback (s*hear heating)* exceeding 100 times the heat produced by radioactivity at depths of 5 to 10 km within the crust. Different numerical scenarios considering the mobility of pore fluids in the sediments suggest that *thermal convection* most probably redistributed heat in the basins and along structural pathways to efficiently cool upper parts of the basins.

2. **Modification underway and Project achievements**

The project was multi-disciplinary coupling field observations, laboratory analysis, and with a strong component of numerical modeling. Remarkably few changes and modifications were necessary during the cause of the research in this project. Numerical modelling was restricted to 2 dimensions. Data obtained from the carbon Raman geothermometry were much fewer than anticipated. The reasons for this (oxidation and fluid flow) stimulated to the design of work presented in the paper investigating fluid flow.

In summary, Alban Souche's PhD thesis demonstrates that *shear heating* and *thermal convection* of pore fluids may have controlled the thermal structure of the Devonian

basins of western Norway. The results of his work have implication for better understanding thermal processes in sedimentary basins formed above large-scale detachments. The products and results of the project closely follow those originally planned in the project description.

3. Publications

PhD thesis:
Souche, A. 2012: *Thermal evoloution in sedimentary basins above large shear zones and detachments.* UiO 2012

Papers:
Souche, A., Beyssac, O., Andersen, T.B., 2012, Thermal structure of supra-detachment basins: A case study of the Devonian basins of western Norway. *Journal of the Geological Society, London,* Vol. 169, pp. 427-434, doi: 10.1144/0016-76492011-155
Souche, A., Medvedev, S., Andersen, T. B., Shear heating during post-Caledonian extensional detachment: implications for the thermal history of the Devonian basins of W Norway. *Tectonophysics* (in review)
Souche, A., Dabrowski, M., Andersen, T. B., Modelling thermal convection in supra-detachment basins: example from western Norway. *Geofluids* (in review)
Souche, A., Dabrowski, M., Andersen, T. B. Medvedev, S., 2011, Modelling natural convection in supra-detachment basins: example from western Norway. (Published extended abstract, Pore2Field conference, November 2011, IFP Energies Nouvelles)
Medvedev, S., Souche, A., Hartz, E. H., Influence of ice sheet and glacial erosion on passive margins of Greenland. *Geomorphology* (in press)

Field guide:
Andersen, T.B., 2011, *The Geology and structural setting of the Hornelen Devonian Basin, Western Norway*. Field guide, 35 pp.

Abstracts for lectures and posters:
2009
Souche, A., Medvedev, S., Hartz, E.H.: Vertical motions of passive margins of Greenland: influence of ice sheet, glacial erosion, and sediment transport. European Geoscience Union General Assembly 2009, Vienna, Austria (Poster)
Souche, A., Medvedev, S., Hartz, E.H.: Erosion driven mass redistribution and vertical motions of passive margins: Examples from Greenland: The 22rd Kongsberg seminar, 6-8 May 2009, Kongsberg, Norway (Poster)
Souche, A., Krotkiewski, M., Dabrowski, M.: 2D convection in saturated porous media: benchmarking numerical solvers. The 22rd Kongsberg seminar, 6-8 May 2009, Kongsberg, Norway (Poster)
Souche, A., Medvedev, S., Hartz, E.H.: Vertical motions of passive margins of Greenland: influence of ice sheet, glacial erosion, and sediment transport. The 11th International Workshop on Modeling of Mantle Convection and Lithospheric Dynamics, June 28 - July 3, 2009, Braunwald, Switzerland (Poster)
Souche, A., Andersen, T.B., Medvedev, S., Dabrowski, M.: Thermal evolution of sedimentary basins above large shear zones and detachments. Vista Scholar Day, Statoil research center, October 2009, Trondheim, Norway (Talk)

2010

Souche, A., Andersen, T. B., Medvedev, S., Dabrowski, M., Thermal evolution of the Devonian basins in western Norway, role of the Nordfjord Sogn Detachment. 29th Nordic Geological Winter Meeting, January 2010, Oslo, Norway (Talk)

Souche, A., Dabrowski, M., Darcy flow in homogeneous and heterogeneous porous media. The European Geosciences Union 2010, Vienna, Austria (Poster)

Souche, A., Thermal evolution of sedimentary basins above large shear zones and detachments. Vista Scholar Day, Statoil research center, September 2010, Trondheim, Norway (Talk)

2011

Souche, A., Andersen, T. B., Medvedev, S., Dabrowski, M., High palaeo-temperatures in the Devonian basins of western Norway: the role of the Nordfjord Sogn Detachment Zone. Vista Scholar Day, Statoil research center, Trondheim, 12 Sept. 2011, Trondheim, Norway (Talk)

Souche, A., Andersen, T.B., Medvedev, S., Modelling heat budget and heat transfer in supra-detachment basins: example from the Solund Devonian basin of western Norway. The European Geosciences Union 2011, Vienna, Austria (Poster)

Souche, A., Dabrowski, M., Rayleigh-Bénard convection in porous media: benchmark of FEM models. The European Geosciences Union 2011, Vienna, Austria (Poster)

Souche, A., Andersen, T. B., Medvedev, S., Modelling heat budget and heat transfer in supra-detachment basins: example from the Devonian basins of western Norway. *Kongsberg seminar 2011*, "Earth systems challenges", Kongsberg, Norway (Poster)

Souche, A., Dabrowski, M., Modelling natural convection in supra-detachment basins: example from western Norway. Pore2field conference, IFP energies nouvelles, 16-18th of November 2011, Paris, France (Poster)

Medvedev, S., Hartz, E. H., Souche, A., Influence of ice sheet, the Iceland hotspot, glacial erosion, and sediment transport on Greenland's passive margins. The European Geosciences Union 2011, Vienna, Austria (Poster)

2012

Souche, A. Volcanic passive margins, Trial lecture PhD defense Nov. 30 2012

Souche, A., Dabrowski, M., Andersen, T.B., Medvedev, S., Heat transfer and fluid flow modelling in supra-detachment basins: a case study of the Devonian basins of western Norway. The European Geosciences Union 2012, Vienna, Austria (Poster)

Souche, A., Andersen, T.B., Medvedev, S., Dabrowski, M. Heat transfer and fluid flow modelling in supra-detachment basins: a case study of the Devonian basins of western Norway. *Institutt for energiteknikk*,18 Jan. 2012, Kjeller, Norway (Talk)

4. Refleksjoner om videreføring (fra prosjektleder)

In this project we have combined *field based observations* and *laboratory data* with *numerical modelling* to *constrain* and *quantify* the influence of shear heating from a large extensional shear zone on the thermal state and fluid flow within a sedimentary basin developed 'piggy-back' in its hanging-wall. We have demonstrated that there may be a strong influence of shear heating on both temperature and fluid circulation in supra-detachment basins.

The numerical codes and parameter testing developed in the project are representative of 2-D problems and for extensional shear zones in continental basins. The models

have been tested for various parameters such as strain-rate, shear zone rheology, shear zone deformation geometry and basin fill architecture. The numerical codes could be expanded for 3-D to test geological data in more realistic basin architectures. The codes could potentially also be modified to represent other basins configurations, for example to be used in regions with overall large-scale shortening, transpression or transtension.