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Microcline Thermochronology: An Approach to Determining Temperature History of Sedimentary Basins

An understanding of the thermal evolution of sedimentary basins is important in a variety of geologic disciplines for reasons related to economic importance of these features and because of implications for lithospheric tectonics and rheology. The importance of understanding the temperature history of sedimentary basins has led to development of a variety of methods of paleothermometry. The usefulness of these approaches is limited in many cases by the complexity of the thermally activated reaction(s) which in turn renders difficult the detailed theoretical understanding needed for precise temperature predictions. Recent work has demonstrated the potential of $^{40}Ar/^{39}Ar$ age spectrum analysis of detrital microclines in revealing this thermochronologic information. By irradiating feldspars with a known dose of fast neutrons, an isotopically distinct but chemically identical form of the daughter (^{39}Ar) is produced from potassium, making the $^{40}Ar/^{39}Ar$ ratio of a geologic sample implicity proportional to age. If the sample has experienced a heating in the temperature range 100° to 200°C for geologic times, the transport kinetics of ^{40}Ar in microcline are sufficiently rapid to cause partial outgassing of the sample. Given that the diffusion parameters for argon transport in microcline are known, a partially outgassed K-spar can yield information related to both the ages of crystallization and reheating as well as the temperature of the heating event. Detrital microcline separates analyzed from deep drill cores obtained from the southern San Joaquin Valley (California), the North Sea, and the Albuquerque basin (Rio Grande rift) yield encouraging results and demonstrate the utility of this approach. In summary, $^{40}Ar/^{39}Ar$ analysis of detrital microcline crystals yields thermochronologic information in the temperature-time range of petroleum maturation and provides this technique with potential as both a useful exploration tool and as a means of probing the fundamental geodynamic processes of basin evolution.

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Some Comments on Two-Layer Extensional Models for Evolution of Sedimentary Basins

Simple extensional models that involve listric faulting in the brittle upper crust and plastic flow in the lower lithosphere have been shown to account for the subsidence history of various continental sedimentary basins and continental shelves. In this paper we present structural evidence that extension in the continental lithosphere during rifting is not uniform. We review evidence that the rifting process in major intracratonic rift basins is spasmodic rather than continuous, that extension and subsidence within the rift during a tectonic phase are generally accompanied by uplift and erosion of the rift flanks, that subcrustal heat input during rifting occurs over an area much broader than the rift proper, and that there may be broad regional uplift before and/or during rifting.

To explain the uplift of the flanks during rifting and their postrift subsidence, we invoke 2 mechanisms: subcrustal thinning by extension below the flanks and tilted major normal faults in the crust between graben and flanks. The uplift and erosion of the flanks due to tilted faults probably do not significantly affect estimates of extension from subsidence analysis, but uplift due to both sources can, in certain cases, be incorrectly attributed to regional uplift or doming.

We present a simplified analysis of the 2-layer extensional model for the elementary case in which extension is instantaneous and the crust is thinned by a different amount from the subcrustal lithosphere. We provide a simple graphical method of data analysis to obtain the parameters that describe thinning of the crust and lithosphere during extension from the subsidence history. Application of this method to the central part of the Pattani Trough in the intracratonic Gulf of Thailand shows that extension and thinning of the lithosphere of a factor of ~ 2 since late Eocene can account for much of the subsidence history and the present-day heat flow. Our analysis suggests that thinning of the crust in this area is $\sim 20\%$ greater than thinning of the whole lithosphere.

Assuming that none of the lithosphere is removed from the region of extension during rifting, we show by simple geometric examples that a process of nonuniform extension implies that much greater thicknesses of sediment can be deposited in the center of a young basin than in the case of uniform extension of both crust and subcrustal lithosphere. Such an extensional process produces significant uplift of the flanks of the rift and, as a result of erosion of the uplifted areas, the effective cross sectional area of the basin can be increased by as much as 10-20%, depending on the rate of erosion, compared to the area that would have been created by a process of uniform extension. Finally, we show that ultimately it may be possible to compute erosion rates from seismic cross sections of basins.

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Tectosat Study of Northwest European Margin from Satellite Imagery and Structural Data

Landsat imagery can be useful in regional exploration including offshore areas, if used in conjunction with specialized field work.

Our study describes the previously unrecognized Mayo-Svalbard phase and its control on the pre-Hercynian plate configuration, and pinpoints the origin of the Pennine phase found in England and its influence on the North Sea area. It also provides confirmation for the Hercynian event being of mantle diapiric origin triggered by the Caledonian orogeny. Several different phases of Atlantic rifting have been recognized and interpreted in terms of crustal stretching.

Landsat and other remote-sensing images reveal unique information about the brittle fracture pattern of the lithosphere, but a scientific method of working with and using these data in exploration has not been readily available previously.

Our presentation describes a technique evolved by Tectosat over the last decade which integrates Landsat and geophysically derived data with specialized field observations. The Tectosat system uses tectonostratigraphic correlation schemes derived from structural overprint relationships observed in the field, to make a geomechanical analysis of the lithospheric brittle fracture pattern for each recognizable phase of deformation. The result is a method of conducting regional structural studies with greater speed and confidence than previously was possible.

The technique will be illustrated with results from a study of the northwest European margin which has been used by many of the companies currently exploring in the North Sea area. The applicability of the technique to extrapolate into offshore or blind areas will be further demonstrated with reference to a current study of the Barents Sea.

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Source Rocks in Vienna Basin and Their Importance for Hydrocarbon Exploration Along Northern Edge of the Alps

The Vienna basin is a subsidence zone between the Alps and the Carpathians. The basin filling of Neogene age with thicknesses up to 5,000 m is underlain by tectonic units. These are the nappes of the Limestone Alps and the Flysch. Below these tectonic units are the so-called autochthonous sediments and finally the basement. Thickness of this sediment pile can be much greater than 10,000 m. Oil and gas reservoirs exist in all geologic units.

All the crude oils from the Vienna basin belong to 1 major family. Only a single oil exists in the underground of the Molasse; all the other oils from the Molasse zone and the Flysch zone belong to the major family.

Sediments of Upper Jurassic age from the autochthonous Mesozoic are the source for the major oil family. The main phase of oil generation occurs in depths about 4,000 m to 6,000 m. In greater depths this oil source is also a good gas source. Only a few other horizons are able to generate gas, but only lower amounts. Thus, only 1 main source rock for all hydrocarbons, oil and gas, exists in the Vienna basin. The various burial histories of this sediment around the Vienna basin divide this area into regions of different exploration value.

From the geologic point of view, this major source rock can also be found under the Alps. Therefore, the exploration of deep targets along the northern edge of the Alps and under the Alps gets a more positive aspect.