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Thermomechanical Properties and Evolution of Small Pull-Apart Basins

Small pull-apart basins are generally characterized by 2 component subsidence: an initial essentially instantaneous isostatic subsidence (S_i) dependent on the ratio of crustal to lithospheric thickness (C_z/l_z) and the stretching factor β, followed by a slower decaying thermal subsidence (S_t) controlled by the thermoelastic properties of the continental lithosphere, which in turn can be characterized by a thermal time constant τ. Rapid short-lived subsidence (e.g., Vienna basin, Californian Miocene basins) is indicative of either (1) inhomogeneous crustal stretching without major sublithospheric involvement, or (2) extremely small lithospheric diffusivities. The former implies a thin-skinned origin for pull-apart basins and suggests that the spatial and temporal distribution of bounding faults and splays typical of pull-apart basins, result from inhomogeneous brittle failure of the upper crust. However, the effects of lateral heat flow decrease the thermal time constant by allowing a basin to subside more quickly due to both lateral and vertical cooling. The size of this effect is dependent on the width of the stretched lithosphere (the effective τ of a 100 km wide rift is 36 m.y., for a 25 km rift, 6 m.y., whereas the actual thermal time constant in both cases is 62.8 m.y.). Lateral heat flow amplifies rift subsidence while producing complementary time-transgressive uplift in adjacent unstretched regions. However, the flexural rigidity of the lithosphere severely attenuates the deformation caused by the lateral flow of heat. Whereas the deformation is highly dependent on the mechanical properties of the lithosphere, τ is independent.

Continental lithospheric rigidities appear to increase with age following an orogenic or thermal event, suggesting that the long-term mechanical behavior of the continental lithosphere is similar to that of the oceanic lithosphere. However, high rigidities (10^{32} dyne-cm) associated with Archean/Proterozoic terranes and modeling of plate deformation suggest that the long-term thermal behavior of continental lithosphere is governed by a cooling plate model with a 200-250 km lithospheric thickness, nearly twice the 125 km estimates for the oldest oceanic lithosphere. This has important implications for the evolution of sedimentary basins. A doubling of the lithospheric thickness implies a quadrupling of τ, yet basin subsidence models have assumed that τ for the oceanic and continental lithospheres are similar. A large τ allows basin subsidence to continue over significantly longer times, but now lateral heat flow, in addition to vertical, must be included in basin models to obtain accurate subsidence and temperature estimates. In particular, S_i is highly dependent on the age of the underlying basement. These principles are illustrated both theoretically and with reference to the European Alpine foreland, upper Paleozoic foreland basins of North America, and Californian Neogene basins.

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Geochemical Relationship Between Petroleum and Coal

Large oil pools and coal beds are occasionally found associated within the same sedimentary series, but mostly in tertiary basins. For some of these series it has been demonstrated that the oil originated, at least partly, in the coal beds. This is probably true for more of them, although it was not demonstrated, given the lack of geochemical studies.

In Paleozoic series, which account for most coals, at least in Europe, association of oil pools and coal beds is very rare. Moreover the oil pools are small. However, gas pools originating in coal beds have been found, and some are very large.

Pyrolysis studies indicate that most coals, whatever their ages, have a variable but often fair capacity to produce oil in geologic situations. However, for Paleozoic coals, as for many other Paleozoic kerogen bearing sediments, complex geologic history resulted in migration dissipating the generated oil. In some favorable situations, reburial in post-Paleozoic times produced gas, and the presence of very efficient seals (salt) allowed gas pools to form.

Furthermore, petrographic examination shows the exinite content should not be taken as a measure of oil potential, because a large part of this potential lies in macerals which are classified presently in the vitrinite group.

Careful use of the methods of petroleum geochemistry will increase the chances of finding oil pools in Paleozoic coal measures of Europe.

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Hydrocarbon Habitat of East Shetland Basin and North Viking Graben of Northern North Sea

In the East Shetland basin, Late Jurassic rifting formed tilted fault blocks and unconformity traps sealed by onlapping Cretaceous mudstones. Important oil-bearing reservoirs are Middle and Lower Jurassic marginal/nonmarine sheet sandstones and restricted Upper Jurassic submarine fan/shallow-marine sandstones. Mature Upper Jurassic mudstone and Middle Jurassic coal source rocks located in half grabens downdip of the major fields, and in the flanking western Viking graben, generated oil in Eocene to Miocene time.

Study of reservoir pressures, distribution, and structure defines the major Jurassic aquifers in the East Shetland basin. The geometric relationship of these aquifers to the source rock kitchens defines the volumes of source rock drained by the major oil fields. Quantitative modeling of the volume of oil generated and expelled from the source rocks (from geochemical and compaction data) accounts for the inplace reserves of the fields.

In the Viking graben, deeply buried Jurassic fault blocks that now contain mainly gas condensate and high pressure salt water were sourced with oil in the Late Cretaceous to Eocene, and with gas in the late Eocene to Recent. Extensive vertical migration of oil has occurred from Jurassic source rocks and reservoirs through thick, microfractured, overpressured Cretaceous mudstones, up the fault zones reactivated in the Tertiary, and into an extensive Paleocene/lower Eocene aquifer sealed by Eocene mudstones. The oil was probably degraded during Miocene freshwater flushing, and displaced out of lower Tertiary traps up onto the East Shetland platform by subsequent gas migration.

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The Mediterranean Sea: Its Origin and Evolution

The Mediterranean Sea is a net result of colliding continents, Using a Pangaea and a Gondwanaland reconstruction and plate tectonic models, the authors describe the origin and evolution of the Mediterranean Sea. From the beginning of the gradual disappearance of the Tethys sea (which was the ancestor of part of the Mediterranean), concurrent with the beginning of the formation of the Alps, to approximately 5 m.y.B.P., the Mediterranean region has evolved through extreme change. Approximately 200 m.y.B.P., during the Jurassic, as a result of African and Eurasian plate movements (and subsequent microplate movement in surrounding areas), the Tethys began to contract, and by approximately 65 m.y.B.P., it was completely closed to form an inland sea, the Mediterranean.

Since that time, the Mediterranean Sea has progressively widened and deepened due to subsidence, rifting, and sea-floor subduction. The movements of the Iberian plate alternately closed and reopened the Mediterranean "gate" to the Atlantic Ocean. From approximately 12 m.y.B.P. to approximately 5.5 m.y.B.P., parts of the sea completely dried up and periodically refilled due to these movements. Massive evaporite deposits that covered parts of the sea floor to depths of as much as 2 km in places are striking evidence of these closed phases. However, in the future the geologic stability of the region could once again be shattered, plate movements could again close the Atlantic "gate," and parts of the Mediterranean could again become deserts.

Continuing research and probing of the depths of the sea will provide the data needed to better understand the plate movements of the past and guide us to the formulation of models of plate movements of the future. The study of such plate movements will also add to a better understanding of the deposition of sediments and the tectonics pertinent to the accumulation of petroleum. Views of the Mediterranean from space show an interesting perspective of the geologic setting and provide additional clues to areas of potential petroleum deposits.