THERMAL REGIME OF THE UPPER CONTINENTAL CRUST OF THE EXMOUTH PLATEAU REGION, OFFSHORE NORTHWEST AUSTRALIA.

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The Exmouth Plateau is a submarine marginal plateau with an area of about 150,000 square kilometes situated off the northwest Australian continental margin (Fig 1). The plateau consists of deeply rifted and subsided continental crust. It is bounded to the north, south and west by oceanic crust. At its crest, the plateau is 800 metres below sea level and sedimentary thicknesses, consisting of pre-breakup Paleozoic to early Mesozoic sediments and post-breakup Mesozoic and Tertiary sediments, are up to 10 kilometres.

In 1986 the Division of Marine Geosciences and Petroleum Geology of the Australian Bureau of Mineral Resources, Geology and Geophysics acquired an extensive set of 41 marine heat flow values over the Exmouth Plateau during two cruises of the research vessel RIG SEISMIC (Choi et al., 1987; Exon et al., 1988). A further 58 heat flow stations were occupied in early 1987 during a survey by the Australian National University, Department of Geology aboard the CSIRO research vessel FRANKLIN (Edwards, 1987; Swift et al., in prep).

The present day heat flow pattern for the Exmouth Plateau region has been compiled from these data as well as from heat flow values determined from thermal geohistory analysis of 23 oil exploration wells in the region. The surface heat flow pattern is shown in Figure 1. The overall average for the region is 56 mW/m**2, however the points of interest in the heat flow pattern are: the area of low heat flow (as low as 17 mW/m**2) in the centre of the plateau together with the heat flow high (as high as 100 mW/m**2) to the east on the shelf, and the lack of any heat flow anomalies associated with the margins. The magnitude of the heat flow low is less than the heat flow level entering the base of the crust

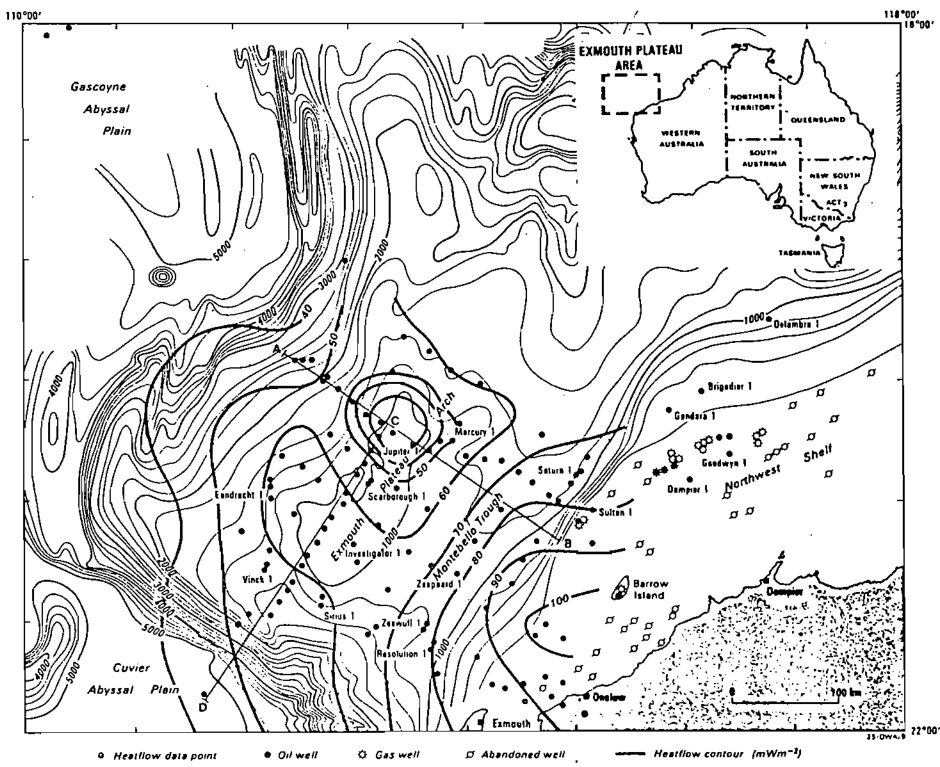

Figure 1. Heat flow map for the Exmouth Plateau region, Northwest Australia.

and so indicates that some process is diverting heat away from the region. In the southern part of the plateau the temperature profiles taken in the sedimentary section are clearly convex upward, which indicates that there is an upward movement of fluid through the sediment at these points. Analysis of these two profiles indicates that Darcy velocities are of the order of 2.0*10**-7 cm/sec. Modelling indicates that there is both a conductive and convective component to the heat transfer within the whole sedimentary section (Swift et al., 1988). It is concluded that there is upwelling of the pore fluids in the high heat flow region and a corresponding downwelling in the low heat flow areas.

The thermal structure of the West Australian Shield has been modelled by Sclater and Francheteau (1970) and is composed of two heat generating zones. The top layer of the crust is 8 kilometres thick and has a heat generation factor of 1.25 micro W/m**3 based on reduced heat flow results. The lower layer of the crust has an internal heat generation factor of 0.25 micro W/m**3. The combination of mantle heat flow and internal heat generation within the crust, 40 km thick, produces a surface heat flow of 42 mW/m**2. Models for the deep crustal structure, based on wide aperture CDP seismic reflection data and refraction ESP data (Williamson et al., 1988) show a major redistribution of the heat producing elements. When these parameters are combined with the structuring to basement level of the Exmouth Plateau, it leads to a pod of low heat production below the heat flow low in the centre of the plateau (Fig. 2), approximtely section AB on Figure 1.

The conductive heat flow model alone (Fig. 2) does not fully explain the measured heat flow lows and highs even though the average for each curve is 56 mW/m**2. The major feature of the modelled surface conductive profile is the heat flow low in the centre of the plateau. This low is due to the pod

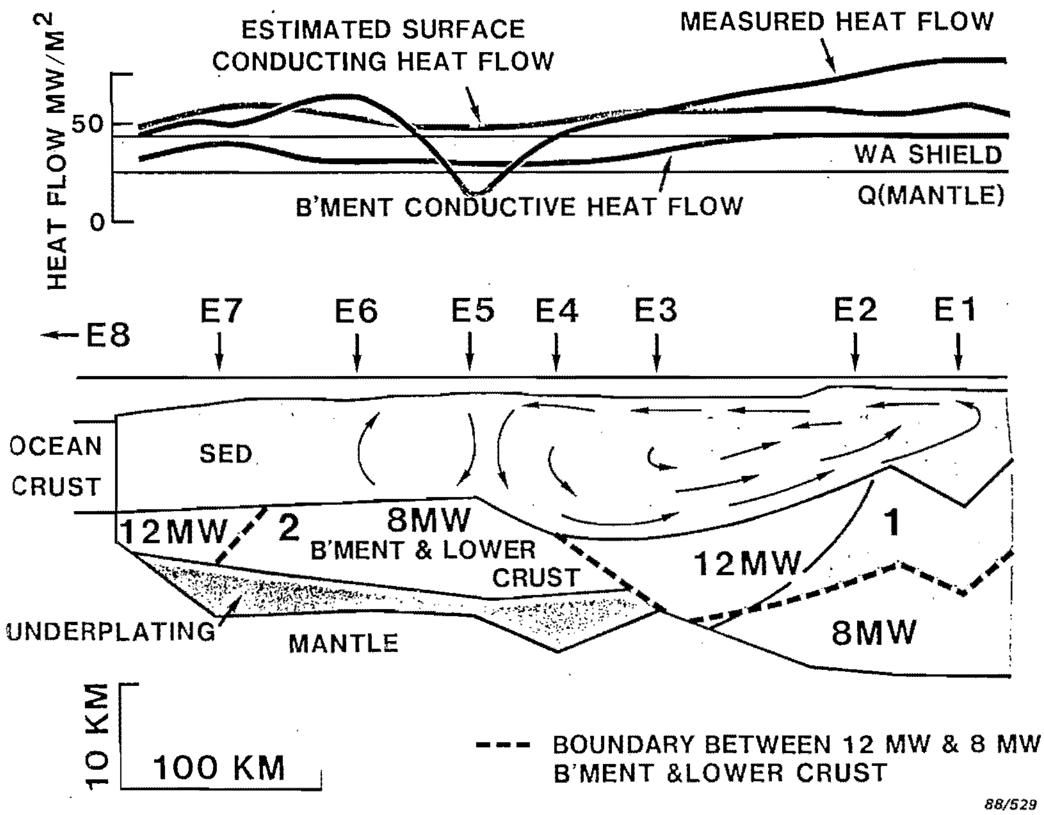

Figure 2. Modelled conductive heat flow profiles with measured surface heat flow profile in relation to deep structure, (Williamson et al., 1988). Along A-B in Figure 1.

of initially lower crust which has a low heat production rate, and can also be seen on the curve representing conductive heat flow on the top of basement. The latter curve shows good agreement with the WA Shield average in all regions except in the centre of the plateau and towards the plateau margin in the west where the crust has been thinned.

Unlike the WA Shield there has been up to 12 kilometres of sedimentation on top of the basement in this region. The average surface heat flow is 56 mW/m**2 not 42 mW/m**2 as is found on the WA Shield. The difference corresponds to an internal heat production rate of 1.4 micro W/m**3 for the sedimentary section. There is a correspondence, however, of the conductive heat flow low and high at the top of basement and the measured conductive/convective surface heat flow. The differing thermal properties of the basement result in one region of the plateau being heated more than the other. Convection occurs because the higher temperature on the eastern side at basement level leads to density differences and hence buoyancy forces relative to the cooler western side, resulting in the hotter fluid rising while the cooler side sinks. This model is not the classic convection model as it does not use an even heat source at the bottom boundary. With a lateral variation in heat flow it is much easier to get convection, and the model does not suffer from the Rayleigh Number criterion or other associated restrictions. The average Darcy velocity required to produce the observed surface heat flow pattern is about 3*10**-9 cm/sec, with permeabilties of about 10**-2 millidarcy. The low flow rates imply that the convection cell is a low Rayleigh Number flow.

In the case of the Exmouth Plateau, the average fluid velocity is 3*10**-9 cm/sec which implies a horizontal temperature gradient of 0.08°C/km or more is required to produce a convection cell on the scale implied by the surface heat flow pattern. When considering the whole thermal structure of the model in Fig. 2, the horizontal temperature gradient at basement level is in the order of 0.2° C/km. That is, the thermal structure at basement favours convection within the overlying sediments. The surface heat flow above the rising column will be higher. Consequently, a lateral variation in the heat flow at basement level will be accentuated at the surface because of convection.

The presence of such a large single convection cell, 200 km long and 10 km deep, due to such a low variation in background heat flow and low overall heat flow has major implications to the likelihood of convection cells in other major sedimentary enviroments. Namely, that it is likely that convection is occuring in most sedimentary basins of the world.

In conclusion, the thermal structure of the upper crust on the Exmouth Plateau is characterised by a major redistribution of heat producing elements to basement level. The resultant lateral heat flow variations have produced a large scale convection pattern in the sedimentary section which has perturbed the surface heat flow pattern.

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