tation of the seismic data in terms of the current understanding of the rheological properties of the crust and upper mantle?

It seems reasonable that the Archaean continental crust was differentiated much as it is today[2]—in which case anhydrous mafic granulites seem to be the likely material composing the lower crust. The "smearing out", we mentioned, would require this material to be ductile at its base. We used 38 km for the crustal thickness because it is the present average for the region under study. A 70-km thick Archaean crust seems unlikely as the Dharwar schist belts now exposed on the surface are only in the greenschist facies.

We do not believe that the possible range of values for the differential stress considered by Koch (tens to thousands of bars) is the probable range. Recent studies[3] tend to suggest low stresses (10–100 bar) associated with contemporary asthenospheric flow. Similarly $10^{-14}\ s^{-1}$ is considered to be a geologically representative strain rate[4].

Unfortunately rheological behaviour of geological materials in the above mentioned conditions is also not known uniquely. For example, the flow law of Goetze[5] for olivine, reported to be valid below 2 kbar, yields a flow temperature of 1,235 °C for $\sigma = 20$ bar and $\dot{\varepsilon} = 10^{-12}\ s^{-1}$ as compared with 1,040 °C from the law used by Koch. There is also the problem of extrapolating experimental values to low stresses and strain-rates.

Figure 1 shows the dependence of the flow temperature on differential stress for three compositions and three strain rates using flow laws for quartz[6], diabase[7] and olivine[5]. Clearly, the temperature is sensitive to chemical composition and the sensitivity increases as the differential stress decreases. Thus, if the smearing out of the base of the crust took place under relatively low stress fields (tens of bars), then the chemical composition becomes a particularly important factor in determining the actual temperature of the process. For a strain rate of $10^{-14}\ s^{-1}$ we obtain a temperature range between 780 °C for diabase and 1,080 °C for olivine at 20 bar. If, as we had inferred, the structural discordance at 38 km is taken to indicate that the mantle (olivine) below was ductile and convecting, then, in the abovementioned stress and strain rate conditions, a temperature of $\geq$1,080 °C and a gradient $\geq$28 °C km^{-1} are implied. As olivine appears stronger than other rock forming materials, this model requires that the lower crust must then have been ductile as well, and hence the base of the lithosphere must have been above the Moho—crust being defined in chemical terms without consideration of its rheological properties. If, on the other hand, the boundary marks that point in time when the descending brittle–ductile boundary in the crust reached its base, then in the same conditions, a temperature of 780 °C, and a gradient of 20 °C km^{-1} is implied for a 'diabasic' type lower crust.

Note that the thermal gradients inferred above are entirely consistent with those claimed in our original paper, which were based on experimental evidence on the beginning of melting in silicate rocks[8]. With declining heat flow, model 1 would evolve to model 2, and in the interim, the lithosphere would include a ductile lower crust above a brittle upper mantle ("jelly sandwich") (J. Suppe, personal communication). Although model 1 may well have applied in the early Archaean, model 2 seems to be more reasonably associated with the onset of cratonic stability—which marks the end of the Archaean.

Clearly evolution of tectonic style in the Earth is associated with declining heat flow. Consideration of lithospheric evolution in rheological terms, with progressive descent of the brittle–ductile boundaries in both crust and mantle, as the Earth cooled, may help to explain the more abrupt changes.

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Behaviour, paternity and testes size

IN a recent issue of *Nature*[1,2], Martin and May, and Harcourt *et al.* proposed a theory that behaviour, paternity and testes size are related. This hypothesis is interesting but suffers from the use of, as a model, species in which sperm production per unit of testes, sperm per ejaculate and other important considerations can only be surmised. Perhaps larger testes size is a result of more frequent copulations or larger testes stimulate males to copulate more frequently. Are sperm numbers per ejaculate well correlated to testis size in primates? The boar, ram and bull have roughly the same testis size but daily sperm production per gramme of testis varies greatly between them, and the number of sperm per ejaculate is 10–50 times greater in the boar than in the bull or ram.

The time of mating relative to ovulation seems to be more important than any other one factor in determining paternity when two males are used at an interval in the rabbit, pig and sheep[3,4]. When matings or inseminations of two males are coincident, then the fertility of the male and numbers of sperm determine paternity. With all these complex interactions playing an important part, it seems overly simplistic to ascribe much to testes size.

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HARCOURT REPLIES—I agree, as stated in our paper[1], that not only are more data needed to prove fully the idea that relative testes size is related to breeding system via sperm competition but also that other factors influence the correlation, and also agree that the association between relative testes size and sperm output is largely an assumption. Nevertheless, I would argue that the correspondence between the data and predictions based on this assumption is so good that unless another hypothesis explains equally well the association between relative testes size and breeding system, ours (with its assumption) must stand as the best explanation of the correlation.

Four points can be usefully commented on in more detail. (1) Although data are lacking on, for example, sperm numbers per ejaculate, they are not totally absent, and what information there is supports the hypothesis[1,2].

(2) Dziuk writes about testes size *per se*; we consider relative testes size, that is, testes weight per unit body weight. The difference is extremely important, and the fact that the boar, with a greater relative testes size than the bull (and I believe the ram?), produces more sperm per ejaculate than does the bull or ram fits our theory and its assumption.

(3) Timing of mating in relation to ovulation is of prime importance in determining paternity. However, primate males cannot judge precisely the time of ovulation. In this situation the male that inseminates the largest amounts of sperm over the longest periods will be at a competitive advantage when more than one male mates with the periovulatory female. Our argument is that to do this he requires a large volume of spermatogenic tissue and hence large testes. Dziuk implies just this

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