

carbon (Fig. 1). A normal mantle source, however, seems insufficiently rich in carbon to explain the observed  $\text{CO}_2$  enrichment of granulites. Nor could it generate the  $\text{CO}_2$  flux necessary to convert amphibolite to granulite<sup>10</sup>. Furthermore, metamorphosed crustal carbonates also have  $\delta^{13}\text{C}$  values in the same range<sup>10</sup>. Although marine limestone has  $\delta^{13}\text{C} \approx 0$ , this value will be driven down to negative values by partial decarbonation caused by regional or contact metamorphism, or by exchange with organic carbon or juvenile  $\text{CO}_2$ . High-grade metacarbonates with a long crustal history (as might be expected for those in the deep crust) typically have

granitic magma bodies, and episodic  $\text{CO}_2$  fluxes, consistent with the inferred petrogenesis of southern Indian charnockites. This model is particularly appropriate if some of the massive charnockites are indeed magmas with high  $\text{CO}_2$  contents (either dissolved or present as a free vapour phase) rather than transformed metasediments.  $\text{CO}_2$ -rich magmas and associated large  $\text{CO}_2$  fluxes could be a natural consequence of crustal growth processes involving underplating of mantle material beneath a carbonate-bearing lower crust.

It is interesting to note that large  $\text{CO}_2$  fluxes are observed in hydrothermal

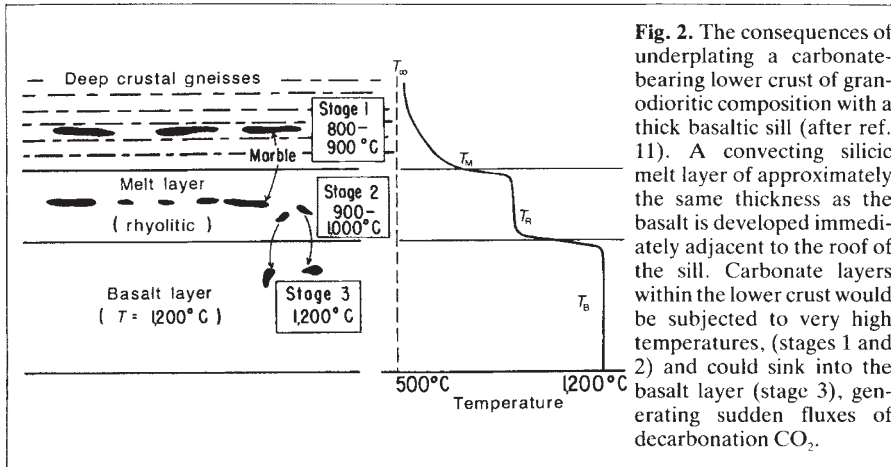


Fig. 2. The consequences of underplating a carbonate-bearing lower crust of granodioritic composition with a thick basaltic sill (after ref. 11). A convecting silicic melt layer of approximately the same thickness as the basalt is developed immediately adjacent to the roof of the sill. Carbonate layers within the lower crust would be subjected to very high temperatures, (stages 1 and 2) and could sink into the basalt layer (stage 3), generating sudden fluxes of decarbonation  $\text{CO}_2$ .

$\delta^{13}\text{C}$  values in the range +2 to -10. Carbon isotope data, therefore, do not distinguish a unique source for the  $\text{CO}_2$ , although it must be exotic to the sample locality<sup>9</sup>.

Further systematic analysis of carbon isotopes in  $\text{CO}_2$  in both fluid inclusions<sup>2,4,6</sup> and cordierite<sup>1</sup> from localities at various structural levels throughout the terrane, combined with regional oxygen- and strontium-isotope studies, could help to constrain its origin further.

At least two and possibly three different charnockite-forming events, each involving a  $\text{CO}_2$  influx at least on a local scale, have affected the deep crust of southern India. This suggests that the  $\text{CO}_2$  source lies in the Indian crust or mantle lithosphere. Either could be enriched in carbonate; Central Highland Series granulites in Sri Lanka contain 5 per cent carbonate layers by volume, and mantle-derived carbonates and other alkaline igneous rocks occur sporadically throughout southern India. A crustal carbonate source is probably quantitatively more significant and could be mobilized during underplating and partial melting of the lower crust (Fig. 2). Underplating could generate large-scale melting<sup>11</sup> at 900–1,200 °C and promote high-temperature, total decarbonation of partially decarbonated marble layers (stages 1, 2 and 3 in Fig. 2). The combined process would result in high-grade metamorphism, melting, emplacement of  $\text{CO}_2$ -saturated

systems associated with zones of active extension and volcanic activity, such as the Massif Central<sup>12</sup>, where mafic intrusion and underplating might be expected to be occurring at depth.  $^{15}\text{C}/^{12}\text{C}$  isotope ratios are typically in the same range as that shown by granulite fluid inclusions, but no significant  $^3\text{He}$  anomaly is observed, implying that the source for the emanations is dominantly crustal. This further emphasizes the importance<sup>13</sup> of metacarbonate layers in the deep continental crust as a significant source for large fluxes of  $\text{CO}_2$ . □

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## Daedalus

### Fine spread of colour

PAINTING is one of the most expensive, tedious and unsatisfactory of technical operations, whether conducted by large-scale dip coating and stoving, or by slow old brush. Worse still, the paint is bound to fail or wear off sooner or later, when it must all be done again.

Daedalus, however, feels that painting ought to be easy. A liquid must spread spontaneously over a surface if the process releases surface energy. Some liquids spread on other liquids in this way; but surface energies are generally too low (less than 1 joule per square metre) to drag a liquid over a solid surface at a useful rate, even if the energy balance favours it.

But, says Daedalus, suppose the liquid reacts with the solid surface. Chemical energies are so great that spreading could now be favoured by many kilojoules of released energy per square metre. A chemically reactive paint should not only spread strongly across a horizontal surface: it should even be able to haul itself up a vertical surface against gravity.

To test this cunning notion, Daedalus is devising a self-spreading paint specifically for metal surfaces. DREADCO's chemists are compounding polysulphide paints which react with a metal surface, binding the paint firmly with sulphide bonds and releasing much energy in the process. The resulting 'autopaint' should spread vigorously over metal and adhere with great tenacity. A metal object dipped even partially into autopaint will soon be completely covered by the rapidly spreading film.

Autopaint will need careful handling. It will tend to climb out of its can and spread relentlessly over all available metal. A region to be coated with autopaint will need a boundary drawn round it in wax crayon, as a barrier to further progress. Even so, autopaint with its chemical adhesion may simply burrow under and displace the merely physically adhering wax, and continue ruthlessly on its way. But this alarming characteristic may also be a virtue. Applied to a dirty or rusty surface, autopaint will burrow under the grime and protect the metal perfectly from beneath.

Thus autopaint will rescue all existing conventionally painted metal objects: lamp-posts, locomotives, gas-holders, bridges. Simply expose the bare metal in a few places, and keep them topped up with autopaint as it spreads all over the surface under the existing paint. The structure will then be perfectly preserved from the elements, but will still look just as tatty. Industrialists will be content; but car owners, for whom appearance is usually more important than mechanical durability, will probably still prefer old-fashioned repainting methods. David Jones