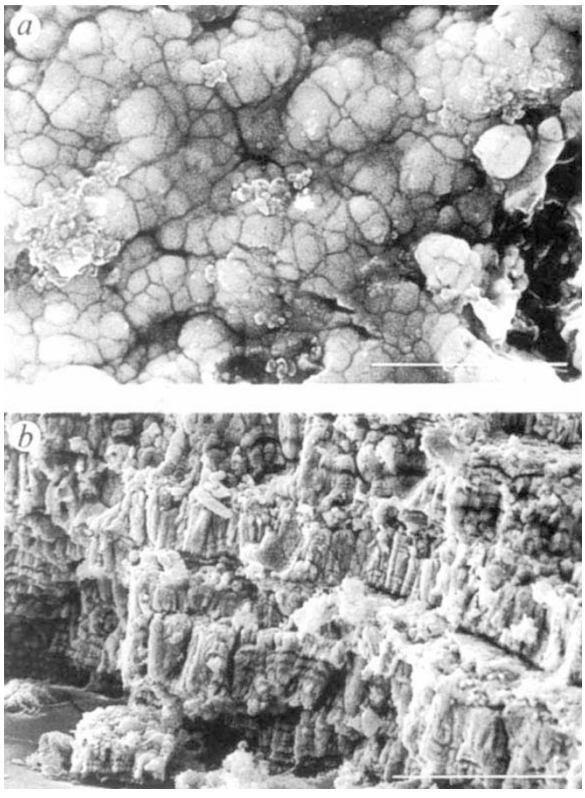
Gold in South Wales coal

SIR — We have found geochemically significant concentrations of particulate gold in coals from the South Wales coalfield. We think this is the first described record of native gold in coal which demonstrates direct precipitation of the gold at low temperatures. The few previously reported modern instances of anomalously high gold values have been clearly shown to be of detrital origin, related to a neighbouring gold source[1,2].

The gold was initially found as small (2–10 μm) collomorphic grains associated with carbonates (Ca, Mg, Fe, Mn), sulphates (Ca and Ba), clays (kaolinite and illites), sulphides (Fe, Co, Ni, Cu, Zn, Mo, Cd, Pb), Pb selenides and trace oxides and phosphates within closely spaced, bed-normal fractures (cleat) in several Middle Coal Measures coals of the anthracite region in the northwest of the coalfield. Gold was concentrated from these coals by ashing at 850 °C and maceration in hydrofluoric acid. The grains are large (up to 100 × 100 × 20 μm), and tabular to flaky in form. Their thickness varies from 1 to >20 μm. The thinner grains have both flat surfaces smooth, whereas the thicker grains commonly have one surface showing the same colloform texture observed in the *in situ* grains on the cleat (*a* in the figure). In section, the grains consist of elongated gold microcrysts oriented normal to the flat surfaces. The thicker grains consist of more than one layer of microcrysts, each layer being about 1 μm thick (*b* in the figure). We interpret these relationships to indicate that the gold was precipitated on the cleat as a colloid, in association with the other exotic cleat minerals.

Subsequent semi-quantitative (inductively-coupled plasma) analyses of a suite of coals from the Middle Coal Measures showed significant but erratic levels of gold. These were confirmed by 23 assays (using the conventional lead button method on ashed coal samples), and showed gold values up to 4.42 g per tonne of ash, equivalent to 0.137 g per tonne in the coal. Significant variations were detected, both within correlated seams from sites about 40 km apart in the coalfield and from seams at different stratigraphic levels in the same site. The average gold content for the 23 samples of Middle Coal Measures coals in South Wales is 0.60 g per tonne of ash or 0.04 g per tonne of coal. A poor negative correlation between ash percentages and gold levels suggests that the gold is not of detrital origin, and agrees with the form of the gold grains indicating an origin as a colloidal precipitate within the cleat.



Secondary electron scanning electron microscope images of a 100 × 100 × 20 μm gold grain from the Stwrin coal seam at East Pit opencast coal site, South Wales. The grain has been isolated by maceration in hydrofluoric acid from the coal ash. *a*, Surface of the gold grain, consisting of an assemblage of colloidal-sized particles. The underside of this grain is flat, suggesting that this specimen represents the free surface of the grain into the cleat opening. Scale bar, 2 μm. *b*, Cross-section through the gold grain, showing colloform banding in the gold layers. The banding represents textural variations displayed by varying responses in secondary electron imaging and may be associated with microcompositional changes in the gold. Scale bar, 10 μm.

The origin of the gold is unclear. The Clarke value (the average value of a chemical element in the Earth's crust) for gold is not well constrained, but is thought to be around 0.005 g per tonne (ref. 3). The average gold content of these South Wales coals is about an order of magnitude greater than this. Swaine[4] suggests that the average gold content of coal is <0.01 g per tonne, which suggests that the South Wales coals have an anomalously high value. Wedepohl[3] reports that sedimentary rocks have average gold contents around 0.003 g per tonne, somewhat below the Clarke, although there is a well known association of gold with organic-rich sediments giving levels two to three times the sedimentary rock average. Thus the average gold content of these South Wales coals seems high, although there is no evidence as yet that the amounts present are commercially significant.

There are no known gold deposits in South Wales that could have sourced the gold, nor are there any apparent igneous complexes. This does not mean that they do not exist, and the gold in South Wales coals may be an indication of a subsurface deposit. It is also possible that the source of the gold was the anthracite itself. The gold contents of terrestrial plants are poorly known, since most of the analyses come from areas with high bed-rock gold contents[3]. But Wedepohl[3] suggests an average between 0.008 and 0.042 g per tonne of dry tissue. The association of the gold with an exotic carbonate, silicate and sulphide mineralogy on the coal cleat suggests that there is a common origin. A hydrothermal origin has been inferred[5] for the cleat minerals involving deep fluid flow from the Variscan mountain belt of southwest Britain, guided northwards and upwards into the coalfield along a major linked thrust system.

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Whence Geminga?

SIR — Based on the measured proper motion of the star identified as the optical counterpart of Geminga (G″), Bignami *et al.*[1] and Gehrels and Chen[2] speculate that the Solar System may be within the supernova remnant that formed from the Geminga supernova event. But as neither the radial velocity nor the distance of the Geminga optical counterpart G″ is known reliably, the actual space trajectory of Geminga is still poorly defined. I argue here that Geminga may instead have originated in the Orion association, a young association in which supernovae often occur, and in which there is evidence of supernova activity 300,000 years ago. In particular, Geminga may have caused the expanding supernova remnant 'Orion's cloak', which in turn may be linked to the youngest subgroup in Orion, Orion Id in the Trapezium, with an expansion age of around 300,000 years (refs 3, 4).

The parameters needed for the calcu-