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bncdoc.id	CEG
bncdoc.author	Gordon, J E
bncdoc.year	1991
bncdoc.title	The new science of strong materials, or, Why you don't fall through the floor.
bncdoc.info	The new science of strong materials. Sample containing about 36337 words from a book (domain: applied science)
Text availability	Worldwide rights cleared
Publication date	1960-1974
Text type	Written books and periodicals
David Lee's classification	W_non_ac_nat_science

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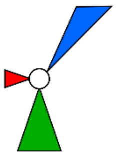

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Footprint
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is nominally and very roughly a sixth of the strength of the bonds elsewhere in the crystal. What Orowan did was to measure the strength of Muscovite mica in tension. In his first experiment he cut from a sheet of mica a normal hour-glass shaped test-piece (Figure 6(b)). This test-piece was flat and quite thin and the planes of weakness lay parallel to the broad flat surfaces. The whole specimen might be regarded, on a molecular scale, as being cut from a number of sheets of paper, weakly glued together. The edges of the specimen, which had been cut mechanically, were, in detail, quite rough. When the specimen was loaded in a testing machine the edges were stressed as much as the middle and so cracks started at the edges and spread inwards across the material in the usual way. The tensile stress developed in this test was about 25,000 p.s.i. (170 MN/m 2), much the same as ordinary glass and perhaps a little less than commercial steel. Orowan now tested a differently shaped specimen of the same mica. In this case the sheet of mica, though otherwise similar, was not waisted but was of a rectangular, playing-card shape, somewhat wider than the clamps which gripped it. It was assumed that the stress followed a path similar to that sketched in Figure 6(a). Thus the edges were largely unstressed. The outside surfaces lying on the stress-path between the grips were, of course, fully stressed and no doubt contained all manner of iniquities in the way of scratches and stress concentrations. For these to extend, however, the crack would have had to cross the planes of weakness in the crystal which were in their path. For a specimen of Muscovite of this shape Orowan found that the tensile strength was about 460,000 p.s.i., that is to say nearly twenty times as strong as a specimen in which the cracks did not have to cross the planes of weakness. 460,000 p.s.i. (3,100 MN/m 2) is about 1½ per cent of the Young's modulus and a very respectable strength. Now Margarite, for instance, which is another kind of mica, quite similar to Muscovite except that it has twice the electrical charge across its planes of cleavage, has negligible strength and is very brittle. This sort of experiment shows however that with materials of this character one cannot really distinguish between practical strength and brittleness so that the introduction of weak internal surfaces can be regarded as raising the strength. Mica and asbestos were of no use to stone-age men for tools and weapons because the planes of weakness run straight through from one side to the other. Jade however consists of

a tangled mass of needle crystals

, tightly packed together but with poor adhesion at the interfaces and might be regarded as an inorganic equivalent to a briar pipe or a bamboo root. Jade is therefore very tough and would have been almost ideal for tools and weapons if only it had not been so difficult to work and so scarce. Since jade cannot be flaked, like flint and obsidian, it could only be shaped by grinding it with sand on a piece of wood for weeks or months. Hence, though very durable, jade implements were very

	costly and partly for this reason, and partly for the beauty and scarcity of the material itself, they remained symbols of prestige after the introduction of metals. Jade is scarce because it can only **crystallize** in **that form** under geological conditions of heat and pressure which were confined to certain faults in the earth's crust. These occurred in the Far East, in New Zealand and in Central America. Jade axes were being made by the Maoris in New Zealand, almost within living memory. According to Heinrich Harrer axes are being made from a jade-like stone in central New Guinea today. He says that the polishing takes several months. A curious problem is set by the discovery of a few jade axes in England recently. If these are not the product of a Piltdown-type hoax, then either there must have been a source of jade somewhere in Europe or else the axes must have been brought an unimaginable distance from the Far East, a journey comparable in its way to that of the monoliths of Stonehenge. However, as Herodotus remarked on finding Scythian artifacts in Delos, they may have 'diffused'. The instances of effective crack-stoppers in minerals are fortuitous. When one looks at biological materials one is impressed with the enormous care which Nature seems to take over the interfaces when she is being, as it were, teleological. A good example is the construction of teeth, about which a certain amount is known. Teeth consist of a hard, tough surface layer called enamel while the interior is made of a material called dentine. Both constituents however contain elongated inorganic crystals distributed in an organic matrix and the principal difference between enamel and dentine lies in the proportion of inorganic material to organic material. The hard part of both enamel and dentine consists of elongated crystals of a substance which is nominally hydroxyapatite,, although the exact chemical composition varies widely, reflecting the environment in which it was formed, and carbonoapatite, fluorapatite, calcium fluoride, calcium carbonate and so on may be present. These crystals are quite small and in enamel are about 3,000 to 5,000, Å in length and from 500 to 1,200 Å thick.