Fossil fuel without fossils

Europe's largest impact crater from an asteroid was created in Sweden's Dalarna region 377 million years ago. The echoes of this energy release can still be heard.

text and illustration | Robert W Williams

The Siljan Ring crater originally measured 65 kilometres in diameter, but has been considerably worn down. Only Lake Siljan has survived the erosion to mark the innermost impact zone.

Over the past two decades, this body of water has attracted much attention in connection with two very different geological issues.

One deals with a biological disaster which eliminated 70 per cent of the species in the Earth's seas, and asks whether Siljan could be linked to this Devonian extinction event.

The other question concerns the possibility that petroleum could be formed by processes other than the ones which have so far been scientifically established.

Stages

The late Devonian period was from 385 to 359 million years ago.

The period was characterised by major disruptions – changes in sea level, at least two large asteroid collisions and two mass extinctions.

Species diversity experienced big, staged reductions. This was one of the five largest mass extinctions in the Earth's history. Numerous corals, sponges, trilobites, brachiopods, jawless fish and many others disappeared.

Identifying the reasons for this great dying demands detailed understanding of dating methods, palaeoclimates, palaeogeography, plate tectonics, sea-level change and the climatic effects of collisions with cosmic bodies.

New dating shows that the Siljan impact occurred 376.8 million years ago, give or take 1.7 million years. The mass extinction took place 374.5 million years ago. That gives a margin of error of just 2.6 million years, which means these two events could have coincided.

However, geochemical data and oxygen isotopes from fish teeth suggest that that the extinction was not caused by the asteroid impact.

The data show a decline in atmospheric carbon dioxide, which could have led to global cooling. Sea surface temperatures dropped by seven degrees in the tropics, where the extinction was most severe.

Taken as a whole, these observations tend to suggest that the Siljan event did not cause most marine life to disappear at the end of the Devonian.

Remarkable

The other issue related to the Swedish crater is a remarkable mix of geology and politics. Some say that Siljan's special geological history might show whether petroleum can be formed abiotically – in other words, without the presence of algae-rich shales or plant-rich coal.

Could complex hydrocarbons form in commercial quantities under extreme pressure and temperature 20 kilometres beneath the Earth's surface, these scientists have asked.

The hypothesis that oil can be created by non-biological mechanisms originated in Russian and Ukrainian scientific circles in the 1950s.

Put briefly, it proposes that petroleum forms deep in the Earth's mantle under extremely high pressure and temperature through a reaction between carbonates, iron oxides and water. This process goes on continuously, and the petroleum migrates upwards through the lithosphere.

At issue is the formation of complex hydrocarbons. There has never been any doubt that simple hydrocarbons such as methane can be formed by inorganic processes.

Methane occurs in the atmosphere of the Solar System's four largest planets, for instance.

Nor is there any question that tiny quantities of such simple hydrocarbons can be formed abiotically on the Earth.

Michael Lewan, a geochemist with the US Geological Survey, reports a 1993 study based on helium isotopes originating in the mantle which concluded that abiotic hydrocarbons account for less than 0.02 per cent of total petroleum production.

The sensational aspect of the abiotic oil hypothesis is its consequences. Hydrocarbons would be created in commercial quantities by inorganic processes deep within the mantle. Future exploration models would have to take this into account.

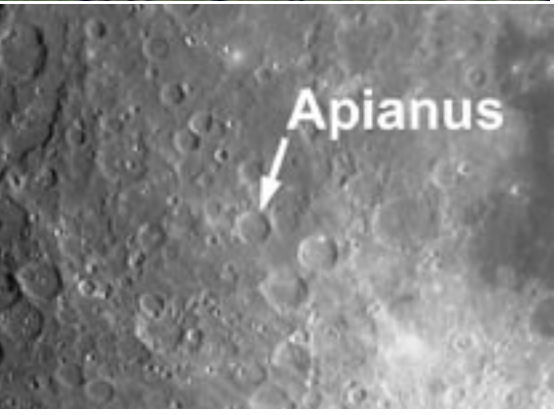
In political terms, confirmation of abiotic formation would mean that oil and gas are renewable resources. Should the formation process be rapid, the hydrocarbon society could continue for ever and talk of "peak oil" would be meaningless.

Many adherents of abiotic petroleum believe that its formation is just as slow as the creation of fossil-based organic petroleum. But some claim to have evidence that the latter does not exist at all. They argue that complex hydrocarbons must have an inorganic origin, or the second law of thermodynamics would be broken.

This view reflects a confusion between *carbohydrates* – believed 40 years ago to be the basis for

Viewed at a distance of 100 kilometres, a big asteroid hits Sweden 377 million years ago and excavates a massive crater. The vegetation in the foreground is tall Protolepidodendron *and* Calamophyton*, an early horsetail.*

The Siljan crater had a diameter of 65 kilometres when it was created 377 million years ago (red circle), but has since eroded away. Several lakes mark its inner area. (Photo: Landsat 7)



Lunar crater Apianus is 65 kilometres in diameter, making it the same size as the Siljan feature. (Photo: R W Williams)

petroleum – and *lipids*, which are fats produced by algae and land-based plants.

The reaction chain from lipids to petroleum actually poses no thermodynamic problems. But the abiotic champions believe that geologists could search for oil and gas in crystalline rocks as well as in sedimentary basins.

Physicist Thomas Gold at Cornell University in the USA convinced investors and the Swedish government that commercial hydrocarbons were to be found six kilometres beneath Siljan.

He considered the crater an ideal place to drill, since the energy from the Devonian impact might have fractured the granite rocks several kilometres below ground.

This zone of fracturing would provide a reservoir for mantle gas, and its upper layer could have been sealed by carbonate infill to act as a cap.

The project actually received financing, and two wells were drilled near Lake Siljan during 1986-92 at a cost of more than USD 60 million. The deeper of these reached a depth of 6.8 kilometres.

Eccentric

Exploring for hydrocarbons almost seven kilometres below ground in undecomposed granite at the heart of the continental shield would be considered highly eccentric by most geologists.

This project conflicted with geological knowledge and petroleum experience – no reservoir rock, no mappable structures with a cap rock, and thereby no hydrocarbons.

More than a century of exploration for oil and gas has shown that petroleum is always found in connection with sedimentary rocks which have a high organic content.

Commercial quantities of oil or gas have been proven in crushed rocks under impact craters in a number of petroleum provinces.

But such formations occur precisely where petroleum is likely to exist anyway – in other words, with organic source rocks and migration routes present. No evidence has been found that petroleum can be discovered in areas without such conditions.

The Siljan drilling yielded about 80 barrels of oily sludge, which is not surprising since organic-rich Ordovician shales overlie the granite and represent an excellent source rock.

Oil traces in Lake Siljan were known to the locals from before. An independent group of geologists assessed the crater in 1984 in relation to abiotic oil production on behalf of Swedish electricity generator Vattenfall.

The geochemical analysis of the trace oil showed that it originated from the Ordovician shale, and the geologists concluded that Gold's claims about its abiotic origin were untenable.

In light of the new data from the wells, Richard R Donofrio – one of the original research team – updated its report in 2003 and said that nothing had been found to affect its conclusions.

So it would still seem that fossil fuel derives from ancient organisms.

Unpleasant

The world has become an unpleasant place to live on several occasions over the past 700 million years. Many natural ways of damaging the biosphere exist.

To prevent this from happening again, it is important that we are familiar with all these natural means – and that in turn demands good science.

Studies of the Siljan area have made important contributions to our understanding of geological history and crater formation. We have also learnt that exploring for hydrocarbons on the basis of erroneous exploration models and faulty science is an expensive business.

Bombarded

The Earth is constantly bombarded by objects orbiting the Sun. At a height of 150 kilometres, the US space shuttle is hit by 33 000 particles per second.

These measure only 0.001 millimetres, and the frequency of the collisions declines with the size of the object. One big enough to form a crater hits the Earth's surface once a year.

Those sufficiently large to cause a powerful explosion collide once or twice a century, and impacts the size of Siljan occur on average every five million years.

If all the impact craters ever formed had been preserved, the Earth's surface would have looked just like the Moon.