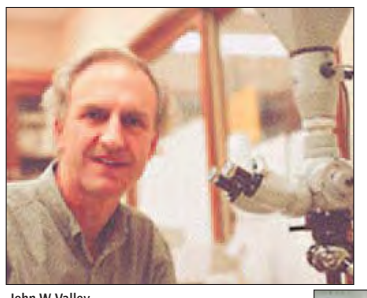
Zircon makes the grade

DOUBTS ABOUT A CLASSIC TIMEKEEPER USED IN GEOLOGY HAVE BEEN PUT TO REST, SAYS **S ANANTHANARAYAN**

Assessing the antiquity of the very ancient earth calls for finding things that were around at that far off time. Most rock or minerals that are on hand now were formed later on or have changed and corroded, to be of no use in counting the years. Zircon, an extremely hardy mineral, is an exception and, as it contains traces of radioactive uranium and thorium that decay into two forms of the lead, it has been possible to date samples as far back as 4.4 billion years.

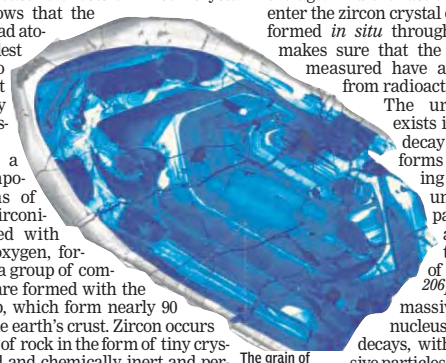
But this same feature of radioactivity ravages the crystal structure of zircon and leads to a migration of decay products, which has raised questions about how reliable date assessment based on zircon crystals can be. John W Valley, Aaron J Cavosie, Takayuki Ushikubo, David A Reinhard, Daniel F Lawrence, David J Larson, Peter H Clifton, Thomas F Kelly, Simon A Wilde, Desmond E Moser and Michael J Spicuzza, of Wisconsin, Puerto Rico, Perth in Australia and Ontario in Canada report in the journal *Nature Geoscience* that their detailed study of radioactive effects on zircon crystal structure shows that the mobility of lead atoms in the oldest samples is too little to affect the accuracy of age assessment.



John W Valley.

Taksyuki Ushikubo, John Valley and Noriko Kita at the Secondary Ion Mass Spectronomy laboratory as Wisconsin.

Zircon is a mineral composed of atoms of the element zirconium, combined with silicon and oxygen, forming part of a group of compounds that are formed with the silicate group, which form nearly 90 per cent of the earth's crust. Zircon occurs in most kinds of rock in the form of tiny crystals. It is hard and chemically inert and persists unchanged in form in most occurrences of sand and is a common trace constituent in hard rock.



The grain of zircon.

Uranium and thorium atoms often find a place in the crystal structure of zircon, but the element lead is positively rejected. This is a useful feature because uranium and thorium atoms are radioactive and decay, after some steps, into forms of lead. The levels of uranium or thorium and lead, in a sample, can thus indicate the age of the sample since it was formed. The ratio of the different forms of lead that are found in the sample can also indicate the age. And the fact that lead cannot enter the zircon crystal except by being formed *in situ* through radioactivity makes sure that the levels of lead measured have actually arisen from radioactivity.

The uranium (U) nucleus exists in two forms and their decay leads to different final forms of lead (Pb). One starting form is ^{238}U, or uranium with 238 massive particles in the nucleus, and this decays, with the emission, in steps, of 32 massive particles, to ^{206}Pb, or lead with 206 massive particles in the nucleus. The other form, ^{235}U, decays, with emission of 28 massive particles, to ^{207}Pb. In the case of thorium, it is ^{232}Th that decays, through 10 steps, to ^{208}Pb. Now, the emission of all these massive particles, usually in groups of four particles, called an alpha particle, result in powerful alpha particle projectiles and also strong recoil of the emitting nuclei.

This is the activity that jostles the zircon crystal structure and in time the crystals could break down to amorphous, or shapeless entities. While the studies conducted are on intact crystals of zircon, the mechanism of conversion of U or Th to Pb, and some features of the variation in levels of residual isotopes found, with ambiguous age estimates, have suggested that there is loss of lead atoms from the samples and this has gravely affected the credibility of the assessment as a means of age determination.

Accurate determination of the age of formation of the earth's crust and the timing of the impact event that is credited with the formation of the moon, are of importance for the understanding of the origins of the internals and the surface of the earth and the moon, and their evolution. Apart from Pb levels, the levels of isotopes of oxygen in zircons also provides a peephole to the quality of oxygen in primordial atmospheres and, hence, the pace of evolution of life. In the context, uncertainty of the reliability of the U-Th-Pb survey in zircon, which is the only method available for age assessment in the four billion-year range, affects a series of conclusions.

Lead atom migration

Although serious questions have been raised based on the possibility of migration of lead atoms as a result of radiation, John Valley and others note in their paper that the matter has not been studied so far at the atom-atom scale and the relation of radiation damage to Pb migration is poorly understood. The group, therefore, worked on a sample particle of zircon derived from pre-existing rock in the Jack Hills, western Australia, and used the methods of Atom Probe Tomography, which is to look into the layers of a material by analysis of the kind of atoms the material gives off as it is etched or evaporated, using an electric field, by Scanning Electron Microscopy, where a surface is scanned atom by atom by a beam of electrons, which get scattered at the surface, and by Secondary Ion Mass Spectroscopy, where secondary emission from the surface is analysed.

Using these hypersensitive methods, the group reached into the core layer of the particle of rock, the interior, which revealed its most ancient age of 4.382 billion years. The outer layers showed an age of about 3.4 billion years, or later growth, at higher temperatures, for which there is geological evidence in the Jack Hills region. And the oldest rock at the core was analysed, using Apt and Sims, to reveal that there had been clear radiation damage, with movement and concentration of lead atoms into clusters, creating peaks and lows in the levels recorded, at a fine scale.

But a detailed study has been able to show that the movement of lead atoms was through short distances and there had been no leakage of lead atoms in the clusters forced by radiation effects. The clustering, or non-uniformity was also at the fine scale and did not affect measurements using methods like Sims, which cover many clusters. The group has described the mechanism leading to anomalous results earlier reported and, with an examination of 409 of the clusters formed, has made a precise assessment of the age of one of the grains of rock, at 3.374 billion years, with an uncertainty of only six million years.

A conclusion drawn is that a sea of molten rock that covered much of the earth was before the formation of the crust and the samples of zircon, and soon after the formation of the earth. The result then constrains the uncertainties in models of how the earth and the moon may have formed. Apart from clearing doubts about the reliability of zircon-based age assessment, the precise methods that have worked with the Jack Hills zircon can now be used with zircon derived from meteorites or lunar samples, for a further understanding.

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Some views of the terrain in Jack Hills, western Australia.

INTENSITY OF ENTRY

TAPAN KUMAR MAITRA EXPLAINS THE MANY WAYS IN WHICH PESTICIDES PENETRATE PLANTS

Pesticides can readily penetrate a plant through its roots, especially if preplanting treatment of the seeds was carried out, or the toxicants were incorporated into the soil. Pesticides penetrate the roots notwithstanding the poor solubility of individual substances in water. This is associated with their solubility in lipids.

Pesticides are evidently absorbed by the roots in the same way as nutrient substances are, by diffusion, exchange adsorption and active transfer of molecules and ions.

This process may be of a passive nature, when the pesticide ions and molecules adsorbed on the surface of the roots penetrate, in an unchanged form, the free space of a cell and further move with the flow of water along the conducting vessels and cells of the green organ tissues. Pesticides may simultaneously enter a plant by metabolism when, being adsorbed on the outer surface of the cytoplasm of the roots' cells, they are immediately involved in intensive metabolism. As a result of biochemical reactions, the pesticides may be irreversibly decomposed or may form complexes with the components of a cell. The intensity of entry via the roots grows with an increase in the dose.

The movement of a pesticide from the soil solution into a plant depends on soil properties. Clay and humous soils greatly adsorb pesticides and in this connection the latter become less accessible to plants. The moisture content of the soil is of considerable importance. The intensive absorption by a plant of insecticides from the soil in conditions of adequate moisture is closely related to the vigorous inflow and movement of water and nutrient substances.

In the treatment of growing plants, pesticides penetrate them mainly through the leaves (cuticle and stoma) in the form of a liquid or vapour. Penetration through the cuticle depends in many aspects on the anatomic and morphological features of the integument tissues.

According to modern notions, the cuticle consists of these unevenly distributed components: cutin — polymerised high-molecular acids and alcohols having simultaneously hydrophilic and lipophilic properties; cuticular hydrophobic waxes — low-molecular ethers of fatty acids and monatomic alcohols of the fatty series with a short chain; pectin — a hydrophobic substance of an amorphous structure permeable to water and polar compounds; and cellulose — a hydrophilic substance with a fibrous structure having high tensile strength.

The cuticle covers the entire surface of a leaf and the substomatic chamber (the surface of the mesophyllous and palisade cells inside a leaf open to the access of air) in the form of a solid film and is the main obstacle preventing the penetration of pesticides in the leaf. It is characterised by a negative charge and can adsorb water. The cuticle has a lipoid matrix, and lipophilic substances can penetrate through it. The ectodesmae of the cuticle are one of the possible ways for the penetration of hydrophilic compounds.

Pesticides penetrate a plant through its leaves only if they are in the form of a solution or emulsion. After crystallisation, no penetration of the substances takes place. Hydrophilic pesticides can enter via the aqueous phase of the cuticle, first into the acid components of the cutin and then into the pectin and water-permeable cytoplasmic membrane. In conditions of increased humidity, the micropores of the cuticle and cutin are saturated with water. With insufficient moisture, the micropores of the cuticle are filled with air, and the drops of the pesticide solution, encountering air locks in the pores, cannot come into contact with the water in them. In this case, the aqueous way of penetration is greatly hampered.

When there is insufficient moisture in a plant, pesticides penetrate in the lipoid way. Lipophilic substances penetrate through the fat components of the cell membrane.

The penetration of pesticides through the cuticle is determined by their solubility in water or in separate components of the cuticle and cell membrane and depends on the degree of their polarity. The cuticle is well permeable to oils, therefore many pesticides soluble in oil readily penetrate it. Having passed through the cuticle and cuticular layers, the pesticide molecules encounter an obstacle along their path to the protoplast in the form of the cellulose layers of the cell membrane. Pesticides may also enter a plant directly through the epidermis, hark, and integument tissues of its stem.

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Pesticides are evidently absorbed by the roots in the same way as nutrient substances are.

No room for complacency

INDIA PROVIDES A MODEL FOR GLOBAL IMPROVEMENT IN ANIMAL HEALTH, WRITES **NEIL SARGISON**

The UK's Chief Scientist has said that as far as global food production is concerned, the world is facing a "perfect storm". This threat combines the ever-growing problems of a global reduction in available productive land, regional scarcities of replenishable water and the failure of drugs and chemicals to control diseases. This warning cannot be ignored. The key to averting catastrophe is in planning ahead, sharing knowledge and in recognising that to do nothing is not an option.

We cannot afford to be complacent. Efficient livestock systems are essential to meet the escalating needs of the world's burgeoning population, so any threat to food production has to be taken seriously. As with all forms of agriculture, livestock production must be economically, environmentally and socially viable. While there are many reasons for the current unsustainability of livestock production, improving animal health affords the greatest potential for a rapid achievement of better production efficiency. In fact, improved animal health addresses the issue of food security, has obvious socio-economic benefits and improves human health standards through the control of zoonotic diseases (those that can transfer between humans and animals), in accordance with the broad principles of "one health".

The situation in India — with a population of about 1.2 billion, cultural and economic dependence on livestock production, a large productive land area and an enthusiastic and receptive veterinary profession — provides a model for global improvement in animal health to meet the requirements for sustainable agriculture.

Improvements in animal health must be founded on robust scientific principles in keeping with the principles of "planned animal health". The University of Edinburgh has an emphasis on animal productivity using precisely that maxim, as well as a focus on production animal genetics, infection and immunity and epidemiology with a strong research focus on the principal constraints, including looking at the issues created by drug resistance. The long-term application of this state-of-the-art epidemiological and post-genomic research will prove to be important in securing efficient and sustainable global animal health management.

In the meantime, everything must be done to ensure that these groundbreaking research programmes and technologies can operate in optimum conditions. The key to this is to address more fundamental veterinary clinical principles. Quite simply, genetic improvements and sustainable disease control programmes can only succeed if animals are first kept alive through good nutrition and basic health management. The focus of veterinary medicine worldwide needs to move away from the needs of individual animals seen out of context at treatment centres or clinics, towards health management of groups of animals within the overall context of their environment, management and contemporary agriculture. There is a need to integrate this approach with cutting-edge scientific research to address the challenges presented by the so-called "perfect storm".

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In partnership with our Indian colleagues, we have the ability to recognise that various scenarios, such as the high rate of calf mortality in Indian buffalo herds, are preventable and can be addressed by identifying the underlying primary causes, rather than deferring to dogma. We are also conversant with the arguments as to why buffalo survival is not necessarily a high priority within the context of the way in which they are currently farmed in India. However, when considering global food production, this situation is inefficient and, I believe, untenable.

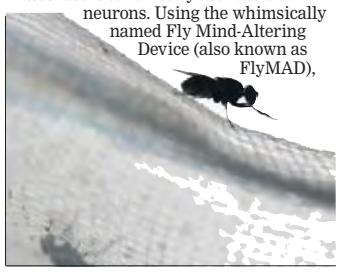
The University of Edinburgh-India collaboration, combining expertise in planned animal health with local knowledge of animal husbandry, infectious diseases and socio-economic factors, to the benefit of global food security aims to minimise the impact of the challenges to global food production.

THE WRITER IS HEAD OF THE FARM ANIMAL SECTION, ROYAL (DICK) SCHOOL OF VETERINARY STUDIES AT THE UNIVERSITY OF EDINBURGH, SCOTLAND. HE ATTENDED A RECENT INTERNATIONAL CONFERENCE IN BANGALORE AND CAN BE CONTACTED AT neil.sargison@ed.ac.uk

PLUS POINTS

Making flies flirt

Neuroscientists have successfully controlled a fly's behaviour with thermogenetics — a new technique that uses lasers to remotely activate brain neurons. Using the whimsically named Fly Mind-Altering Device (also known as FlyMAD),



researchers were able to trigger complex courtship behaviour in a target fly, essentially causing the insect to "fall in love" with a ball of wax.

The research, led by Barry Dickson of the Howard Hughes Medical Institute in Ashburn, Virginia, is similar to optogenetics; a method that activates neurons using light and that has previously been used to control behaviour in mice. However, while optogenetics require fibre-optic cables to be embedded into mice skulls to activate the genetically-altered neurons, thermogenetics achieves the same effect by using infrared lasers to deliver the "instructions" directly to the fly's brain. Scientists have previously influenced fly behaviour by adding a heat-activated protein called TRPA1 to neurons associated with certain actions. When flies modified in this way are placed in a hot box, the targeted neurons activate and trigger certain behaviours. FlyMAD, however, uses a video camera to track the fly as it moves around a box before directing an infrared laser at the insect and activating the parts of its neural circuit that control courtship.

In the picture from *Nature*, the subject fly can be seen attempting to mate with a ball of wax, circling and "singing" to it by vibrating its wings. This courtship behaviour continued for 15 minutes after the laser had been shut off, "suggesting that the heat had triggered a lasting, complex behavioural state".

Another test conducted by the neuroscientists was able to instantly make flies walk backwards by activating TRPA1 that had been added to neurons associated with muscular coordination. The paper written by Dickson and his team is currently awaiting peer review, although some neuroscientists have already welcomed thermogenetics as easier to use than current optogenetic techniques.

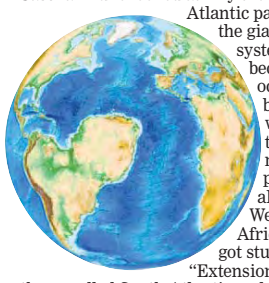
Dickson said he would like to combine the TRPA1 control method with an alternative technique that uses a different light-activated protein known as channelrhodopsin. Scientists say they could then activate different neural circuits at the same time in order to "see which one wins".

JAMES VINCENT/THE INDEPENDENT

What might have been

Geoscientists at the University of Sydney and the GFZ German Research Centre for Geosciences have used sophisticated plate tectonic and 2D numerical modelling to create a map that shows what the earth would have looked like had Gondwana, the supercontinent, broken up differently. It looks at how the world would be completely different if the South Atlantic and West African rift had split, instead of the rift that emerged along the Equatorial Atlantic margins. Gondwana broke up 130 million years ago leading to the creation of South America and Africa. However, for millions of years before this, the southern continents of South America, Africa, Antarctica, Australia, and India were united as Gondwana. It is still unclear why Gondwana fragmented, but it is understood that it first split along the East Africa coast in a western and eastern part, before South America separated.

Researchers Christian Heine and Sascha Brune looked at why the South Atlantic part of the giant rift system became an ocean basin, while the northern part along the West African rift got stuck.



"Extension along the so-called South Atlantic and West African rift systems was about to split the African-South American part of Gondwana north-south into nearly equal halves, generating a South Atlantic and a Saharan Atlantic Ocean," Brune said. "In a dramatic plate tectonic twist, however, a competing rift along the present-day Equatorial Atlantic margins won over the West African rift, causing it to become extinct, avoiding the break-up of the African continent and the formation of a Saharan Atlantic ocean." Their model shows how South America would have been about twice the size it is now, with a huge expanse of land attached to the northeast corner.

HANNAH OSBORNE/IB TIMES