Zircon crystals of Jack Hills and the alphabet to the early history of the Earth

Professor Simon Wilde

At the Scitech Lecture Theatre, on Monday 16th November 2009, sponsored by Scitech, about sixty RSWA members, interested scientists, and members of the public, attended the last of the RSWA hosted-events celebrating the International Year of Astronomy to hear Professor Simon Wilde from Curtin University of Technology deliver a well-illustrated and wide-ranging talk on "Zircon crystals of Jack Hills and the alphabet to the early history of the Earth".

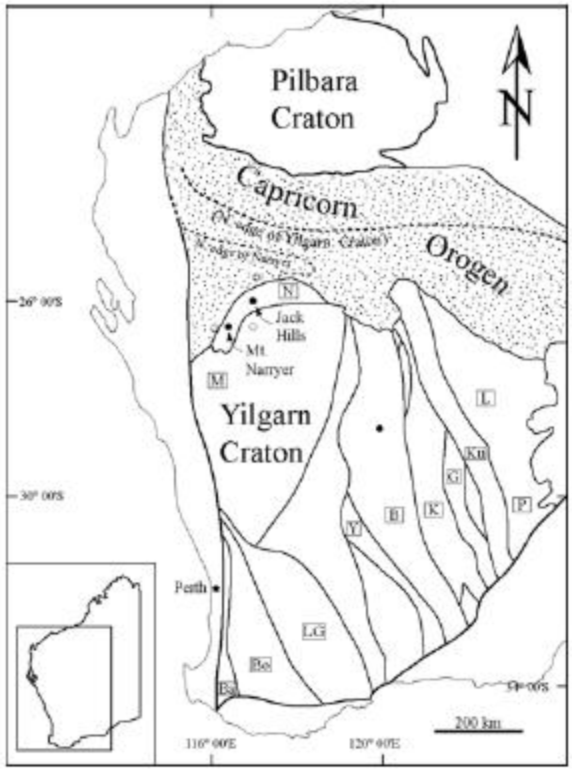
After an introduction by RSWA President Lynne Milne, explaining the theme pursued by RSWA in the International Year of Astronomy, where early in the year the matters covered were Universal and Galaxial, in scale, progressively decreasing in scale to our Solar System, and finally to our home planet Earth, Western Australia's Chief Scientist and Vice Patron of RSWA Professor Lyn Beazley introduced Simon Wilde within the context of the International Year of Astronomy and the significance that Western Australia houses the oldest crystals on Earth.

Simon, in the spirit of the using the Jack Hills zircons as an alphabet to unravelling the early history of the planet, drew on the letters of the elements of the Periodic Table, focusing on key elements that provided information on early Earth environment. Simon initially provided a context for the setting of the zircons: they occur as detrital grains in a belt of siliciclastic rocks, located between younger monzogranites and granitoids, within a tectonic zone along the northern part of the Yilgarn Craton. Simon introduced the audience to the size and chemistry of the zircons, showing that even for their small size the immense amount of information they have yielded. Throughout the presentation, Simon peppered the talk with the history of the unfolding science around the discoveries made in regards to the zircons.

For the first letters of the Periodic Table "alphabet" Simon used Pb, U, Th - elements that provided ages for the zircons. Using SHRIMP, the zircons have been dated to ages as far back as 4 Ga. While there are various age variations in a zircon crystal due to zoning, and other heterogeneities, the zircons have been dated to a maximum of 4.4 Ga.

Oxygen was the next element focused on. Simon compared oxygen isotope data from the Jack Hills zircons with that from zircons elsewhere developed at different stages and environments of the Earth, and with zircons through geological time from Phanerozoic to Archaean. It indicated the Earth was cool enough by 4.2 Ga (possibly by 4.35 Ga) to sustain surface liquid water, there was interaction with surface water, and that there was early recycling of supracrustal rocks.

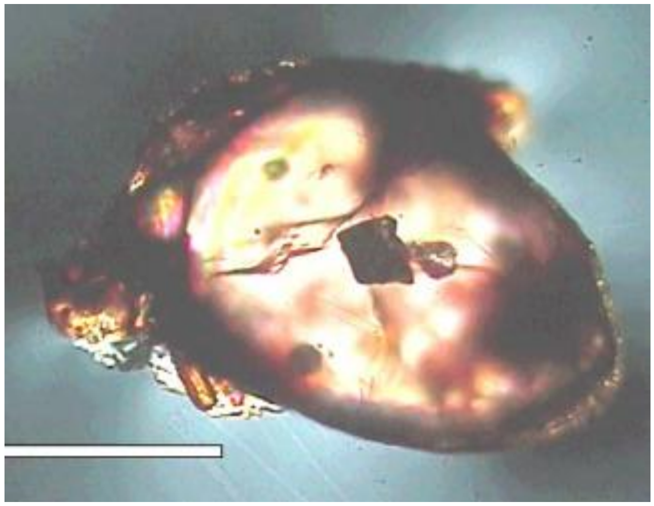
The Rare Earth Elements, including La, Hf, Ce, Y, "alphabet" to provide information on the early history of the Earth. These elements in the Jack Hills zircons were compared with other occurrences in various Earth environments such as magmatic, oceanic crust, continental, and hydrothermal, and the data show that Continental-type crust was present by 4.4 Ga. Specifically the Lu-Hf data indicate crustal growth at ~4.5 Ga, however, there was no evidence for massive recycling of this crust into the mantle, and by implication, no direct support for Plate Tectonics at 4.4 Ga.



Location of Jack Hills in the Nortern Yigarn Craton

Lithium in zircons provided interesting information: The Lithium abundance in zircons is typically > 10 ppm and over 1000 times higher than in mantle-derived magma. Mantle-derived zircon has Li values of < 8 ppb – so cannot be the source for the Lithium in the zircons. Moreover, zircons have fractionated lithium isotope ratios (d7Li = -19 to +14 per mil), i.e., five times more variable than the mantle or oceanic basalts. The zoning in the zircon indicates it is magmatic in origin, therefore Li values therein are primary features. The best explanation for the Lithium patterns is that the zircons crystallised in a rock that had undergone extensive surface weathering, implicating that the parent materials interacted with low T liquid water.
Titanium in the zircons was used as a geothermometer. It showed that most zircons contain less than 20 ppm Ti, the Ti contents of igneous zircons from different rock types show significant overlap, that temperatures average ~650oC for felsic to intermediate igneous rocks and ~760oC for mafic rocks, and that the Ti-in-zircon data for detrital zircons from Jack Hills with ages from 4400 to 4000 Ma have an average T = ~715oC, which overlaps both felsic and mafic rocks - therefore Ti not a good discriminator of source for the zircons.

The final element that Simon dealt with was carbon, both as graphite and as diamonds, occurring as inclusions in the zircons. The diamond in the zircons are not like primitive carbonaceous chondrites, nor like those in meteoritic impact structures, or like those in kimberlites and lamproites, or in komatiites (with very rare zircon), but most similar to those in ultrahigh pressure metamorphic rocks.



Diamond inclusion of the Jack Hills zircons

Diamond and graphite inclusions in 3050 to 4250 Myr old zircon from Jack Hills also suggest that early Earth had a light carbon reservoir. Focusing on d13C: the range in d13C is – 4‰ to – 52‰ with a median of - 30‰, which is different from typical mantle values of - 6‰, but overlaps with metamorphic and some eclogitic diamonds. The results are considered to reflect deep subduction whose low d13C values reflect fractionation by biological processes, so there is a possibility of biological activity as early as 4,250 Ma ago. Whatever the source, the data indicate low d13C reservoir has existed on Earth from the very first stages.

Simon ended his excellent talk with an overall summary of the significance of the Jack Hills zircons in interpreting the early history of the Earth: the Earth's crust was in existence by 4.5 Ga; continental crust and oceans were extensive by 4.2 Ga, marking onset of Archaean; early crust underwent extensive weathering, probably in CO_2-rich atmosphere; the presence of diamonds still not adequately explained, but suggest UHP conditions; carbon isotopes are strongly negative, and not inconsistent, with an organic origin; there was no direct evidence yet for Plate Tectonics on the earliest Earth, but possibly by 4.2 Ga.