

THE KIMBERLEY VOLCANO

On 5 June 2002 Mike Donaldson, a geologist with the Geological Survey of Western Australia (GSWA), presented a copiously illustrated talk on "The Kimberley Volcano". The talk began with "sorry, it's a trick, there is no Kimberley volcano.... But you can see where they have been!"

Most people picture the Kimberley as the sandstone gorges of the northern rivers, the Windjana or Geikie limestone gorges, or maybe the Bungle Bungles. But much of the Kimberley is composed of ancient basalt lavas or their intrusive equivalents. Basalts and dolerites underlie many of the wide valleys between the high sandstone cliffs, and the breakdown of these rocks over time produced the fertile soils that support the Kimberley cattle industry.

The geological make-up of the Kimberley was broadly defined by systematic mapping programs by GSWA and the former Bureau of Mineral Resources (now Geoscience Australia) in the 1960s and 1970s. More detailed studies were carried out in the late 1980s and early 1990s, but only in restricted areas around the margins of the Kimberley. This work included modern isotopic age determinations of the major igneous (ie either volcanic or intrusive) events, including the incredibly precise SHRIMP uranium-lead dates obtained from individual zircon crystals.

Regional airborne magnetic surveys also help to outline the distribution of the relatively highly magnetic basalts and dolerites. Some linear features that extend over hundreds of kilometres, such as the Prince Regent River, can be seen to follow dolerite dykes by the associated magnetic anomaly.

The oldest rocks of the Kimberley are some 1850 million years old. These are granites of the orogenic belts (roots of former mountain ranges) adjacent to the King Leopold Ranges and in the Halls Creek to Kununurra area. Following this there are at least 7 separate igneous events in the geological history of the area:

Ellendale diamondiferous lamproites	(20 million years old)
Antrim basalts & dykes	(515 million years old)
North Kimberley diamondiferous kimberlites	(800 million years old)
Argyle diamondiferous lamproite	(1150 million years old)
Hart Dolerite	(1790 million years old)
Carson Volcanics	(1800 million years old)
East Kimberley mafic-ultramafic intrusions	(1840 million years old)

The east Kimberley intrusions are layered sills, which form spectacular concentric rings of hills such as in the Macintosh Intrusion near Halls Creek, and the nearby Panton Sill. These are being investigated as potential platinum-nickel-copper mines.

40,000,000 years later, the Carson Volcanics poured out onto a shallow sea floor over much of what is now the Kimberley Basin. These basaltic lavas weather to a rich brown soil, which covers the wide valleys that are the basis of the Kimberley cattle industry. Early settlements at Camden Harbour, Kunmunya and Kalumburu attempted to take advantage of these fertile soils, and prolonged tropical weathering of basalts produced the aluminium-rich bauxite ores of the Mitchell Plateau and Cape Bougainville. Although the geology of the Kimberley is complex in some respects, much of the Kimberley Basin area north of the King Leopold Ranges remains relatively undisturbed by tectonic forces despite its great age. The Carson Volcanics exhibit many features typical of modern basalt lavas: lava tubes ("pillows"), vesicles, breccias, and other structures in these dark green to black rocks indicate eruption into shallow seas, and this same environment is indicated by well-preserved ripple marks and mud cracks in overlying sandstones. The flows cover some 250,000 square kilometres, and at an average total thickness of about 500 m, the combined flows constitute some 125,000 cubic kilometres of lava. Quite an event!

Hart Dolerite is about 10,000,000 years younger than the Carson Volcanics, and it occurs as thick intrusive layers ("sills") up to 400 m thick within most of the sandstone units of the Kimberley Basin. It forms distinctive black hills of blocky dolerite boulders, especially in the King Leopold Ranges and the eastern Kimberley. In the northwestern Kimberley it is more common as bouldery outcrops in the floors of narrow sandstone gorges. Columnar jointing ("organ pipes") is common, resulting from uniform slow cooling of the molten intrusive lava.

The next lavas occurred more than a billion years later when the vast outpouring of the Antrim basalt covered probably all of the Kimberley and much of the Northern Territory. Although subsequently eroded off the Kimberley, the Antrim Basalts covered some 400,000 km² and represent one of the world's most voluminous lava fields. Again, quite an event! Some dolerite dykes in the west Kimberley have identical chemical characteristics and age as the Antrim lavas, and they probably represent feeder conduits for the overlying lavas.

The diamond deposits of the Kimberley represent the other spectrum of volcanism in the area. Diamonds occur in explosive volcanic intrusions (pipes or dykes) of kimberlite or its close relative lamproite. In the Kimberley, Argyle is the oldest such deposit at 1150 million years, and it is the largest diamond mine in the world (by volume of diamonds produced). Kimberlites in the King George River area also

contain diamonds, but so far they are uneconomic. They are about 800 million years old. The youngest diamond deposits are at Ellendale, in lamproites a mere 20 million years old. Some of these pipes have recently been brought into production as Western Australia's second diamond mine.

A postscript to the volcano story of the Kimberley is in recent discoveries of tiny gold nuggets in the north Kimberley. The gold is associated with distinctive quartz veins that are typically found in young volcanic environments. These discoveries have resulted in a pegging rush throughout the northern Kimberley. The association of gold, diamonds, platinum, nickel and copper with volcanic or intrusive igneous rocks emphasises the importance of volcanic processes in forming economic mineral deposits.