Remote sensing

Remote sensing for fossils (*April 2014*)

The May 2014 issue of *Scientific American* includes an article on remote sensing that follows what to many might seem an odd direction: how to increase the chance of finding rich fossil deposits (Anemone, R.L. & Emerson, C.W. 2014. Fossil GPS. *Scientific American*, v. **310(5)**, p. 34-39; DOI: 10.1038/scientificamerican0514-46). Apart from targeting a particular stratigraphic unit on a geological map, palaeontological collection has generally been a hit-or-miss affair depending on persistence and a keen eye, with quite a lot of luck. Once a productive locality turns up, such as the Cambrian Burgess shale, the dinosaur-rich Cretaceous sandstone of the Red Deer River badlands of southern Alberta in Canada and the hominin sites of Ethiopia's Afar Depression, palaeontologists often look no further until its potential is exhausted. Robert Anemone and Charles Emerson felt, as many palaeobiologists do, that one fossil 'hotspot' is simply not enough, yet balked at the physical effort, time and frustration needed to find more by trekking through their area of interest, the vast Tertiary sedimentary basins of Wyoming, USA. They decided to try an easier tack: using the known fossil localities as digital 'training areas' for a software interrogation of Landsat Enhanced Thematic Mapper data in the hope that fossiliferous spots might be subtly different in their optical properties from those that were barren.

Satellite image of part of the Wyoming Basin, USA.

The teeth and bones of early Eocene mammals that had drawn them to Wyoming turn up in sandstone beds of the basins. They are pretty distinctive elements of landscape, forming ridges of outcrop because of their relative resistance to erosion, yet for that very reason present a huge selection of possibilities. Being simple mineralogically they also presented a seemingly daunting uniformity. Anemone and Emerson decided on a purely statistical approach using the six visible, NIR and SWIR bands sensed by Landsat ETM, rather than a spectrally oriented strategy using more sophisticated ASTER data with 14 spectral bands. Their chosen algorithm was that based on an artificial neural network that the fossil rich

sandstones would train to recognise patterns present in ETM data recorded over them. This purely empirical approach seems to have worked. Of 31 sites suggested by the algorithm 25 yielded abundant vertebrate fossils. Applied to another of Wyoming's Tertiary basins it also 'found' the three most productive known mammal sites there. So, what is it about the fossil-rich sandstones that sets them apart from those that are more likely to be barren? The authors do not offer an explanation. Perhaps it has something to do with reducing conditions that would help preserve organic material better than would sandstones deposited in an oxidising environment. Iron minerals and thereby colour might be a key factor, oxidised sandstones are generally stained red to orange by Fe-3 oxides and hydroxides, whereas reduced sandstone facies may be grey because of iron in the form of sulfides

New gravity and bathymetric maps of the oceans (*October 2014*)

By far the least costly means of surveying the ocean floor on a global scale is the use of data gathered from Earth orbit. That may sound absurd: how can it be possible to peer through thousands of metres of seawater? The answer comes from a practical application of lateral thinking. As well as being influenced by lunar and solar tidal attraction, local sea level also depends on the Earth's gravity field; that is, on the distribution of mass beneath the sea surface, which depends on how deep the water is and on varying density of rocks that lie beneath the sea floor. Having a low density, the deeper water is the lower the overall gravitational attraction, and vice versa. Consequently, seawater is attracted towards shallower areas, standing high over, say, a seamount and low over the abyssal plains and trenches. Measuring sea-surface elevation defines the true shape that Earth would take if the entire surface was covered by water – the geoid – and is both a key to variations in gravity over the oceans and to bathymetry.

Radar altimeters measure the average height of the sea surface to within a couple of centimetres: the roughness and tidal fluctuations are 'ironed out' by measurements every couple of weeks as the satellite passes on a regular orbital schedule. There is absolutely no way this systematic and highly accurate approach could be achieved by ship-borne bathymetric or gravity measurements, although such surveys help check the results from radar altimetry over such transects. Even after 40 years of accurate mapping with hundreds of ship-borne echo sounders 50% of the ocean floor is more than 10 km from such a depth measurement; in fact 80% lacks depth soundings.

This approach has been used since the first radar altimeter was placed in orbit on Seasat, launched in 1978, which revolutionised bathymetry and the details of plate tectonic features on the ocean floor. Since then, improvements in measurements of sea-surface elevation and the computer processing needed to extract the information from complex radar data have show more detail. The latest refinement stems from two satellites, NASA's Jason-1(2001) and the European Space Agency's Cryosat-2 (2010) (Sandwell, D.T. *et al*. 2014. New global marine gravity model from CryoSat-2 and Jason-1 reveals buried tectonic structure. *Science*, v. **346.** p. 65-67; DOI: 10.1126/science.1258213. **See also** Hwang, C & Chang, E.T.Y. 2014. Seafloor secrets revealed. *Science*, v. **346.** p. 32-33; DOI: 10.1126/science.1260459). The maps throw light on previously unknown tectonic features beneath the China Sea (large faults buried by sediments), the Gulf of Mexico (an extinct

spreading centre) and the South Atlantic (a major propagating rift) as well as thousands of seamounts.
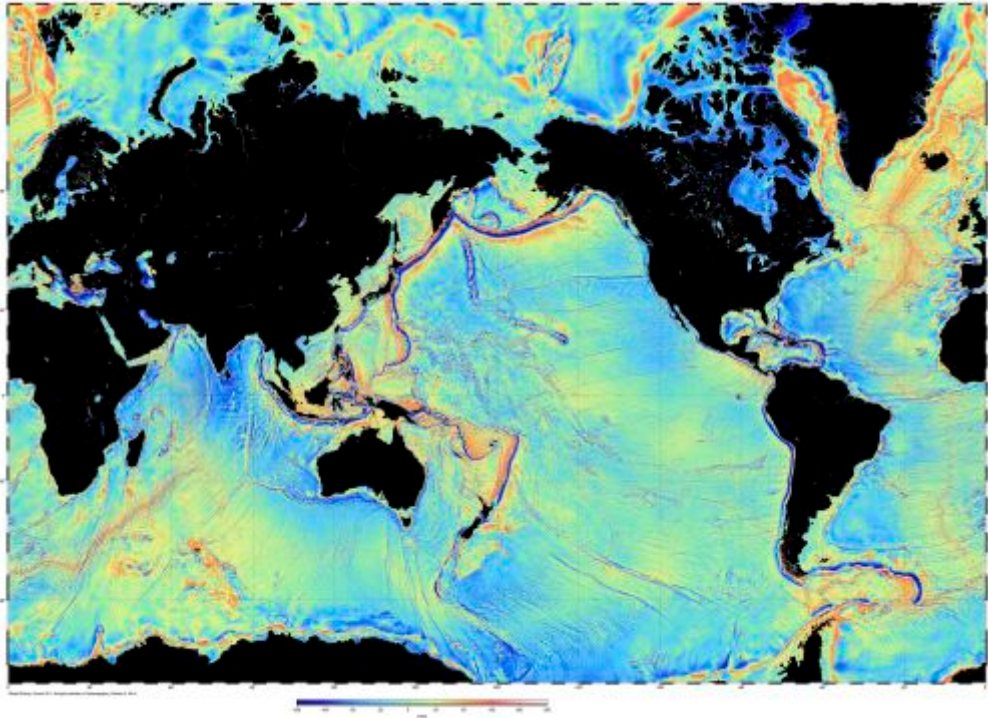
Global gravity over the oceans derived from Jason-1 and Cryosat-2 radar altimetry (Credit: Scripps Institution of Oceanography)

There are many ways of processing the data, and so years of fruitful interpretation lie ahead of oceanographers and tectonicians, with more data likely from other suitably equipped satellites: sea-surface height studies are also essential in mapping changing surface currents, variations in water density and salinity, sea-ice thickness, eddies, superswells and changes due to processes linked to El Niño.