

LECTURE

The geology of bottled water

Summary of the lecture presented to the Society on Saturday 11th January 2004 by Prof. John Mather of Royal Holloway, London University.

As a hydrogeologist, I am often asked about the benefits of drinking bottled water rather than water drawn directly from the kitchen tap. Apart from the fact that the smell of residual chlorine is absent from bottled waters, is it worth either the money or the effort to stock up with water at the supermarket?

Most bottled waters are marketed in the UK as "Natural Mineral Water" or "Spring Water", the use of both names being regulated by the European Commission. A "Natural Mineral Water" is defined as a microbiologically wholesome water, originating in an underground water table or deposit and emerging from a spring tapped at one or more natural or borehole exits. It must be clearly distinguishable from ordinary drinking water by its nature and original state. Both these latter characteristics will have been preserved because of the underground origin of the water, which has protected it from all risks of pollution. In other words a "Natural Mineral Water" is an untreated groundwater. A "Spring Water" comes from a source which has either not applied for recognition as a "Natural Mineral Water" or does not meet the conditions laid down. However, regardless of this it is likely to satisfy the requirements of the regulations which cover the quality of public water supplies. Again a "Spring Water" will be groundwater but might have been treated in some way. Waters marketed with neither of these titles may, for example, be desalinated waters or waters derived from Canadian glaciers, however, most of the bottled waters available in Britain originated as groundwater.

The ultimate source of most groundwater is atmospheric precipitation, rain and snow melt, although deep groundwater may reflect contributions from other sources such as fluid inclusions or formation waters. Much of the chemical character of groundwater is then established within the soil and the unsaturated zone, above the water table. Although there may be little change in total mineralization within the saturated zone, below the water table, it is here that exchange reactions and other processes slowly modify groundwater chemistry.

The composition of rainfall is controlled by the dissolution of atmospheric gases, particularly oxygen and carbon dioxide and by the wash-out of components derived from the sea, land and pollution sources. Thus rain is essentially a dilute solution of carbonic acid and a sea-salt aerosol, plus a variable mixture of sulphuric, nitric and hydrochloric acids. The acidic rainwater has low dissolved solids and rapidly dissolves carbon dioxide which occurs in the

soil as a result of root and microbial respiration and the oxidation of organic matter. The carbon dioxide-charged water is very effective in dissolving minerals. The most common reaction involves the dissolution of calcite. Where there are no carbonates, the chemistry will be controlled by the dissolution of silicate and aluminosilicate minerals, but these are relatively insoluble. Minerals such as gypsum are also dissolved, and pyrite is oxidized to introduce sulphate into the groundwater system.

Within the saturated zone, if groundwater is not yet in equilibrium with carbonate, silica and aluminosilicate minerals, these will continue to dissolve, proceeding towards equilibrium with those minerals available for dissolution. Soluble salts such as halite will dissolve, and a sequence of redox reactions will occur along the flow system. The latter control the hydrochemistry of metals such as iron and manganese and carbon, nitrogen and sulphur species. Cation exchange reactions occur, the most important of which are those taking calcium out of solution and replacing it by sodium, reducing the hardness of water. The sodium generally comes from exchangeable sodium held within clay minerals.

The natural chemistry can be masked by impacts from urban and industrial developments and modern intensive agriculture. The latter is responsible for the major increase in nitrate concentrations seen in many groundwaters over the last three decades.

It is clear from the above that groundwater achieves its composition through a number of interacting factors. However, certain geochemical characteristics, such as the magnesium/calcium ratio, will be determined by the host rock; chloride concentrations may be controlled by atmospheric inputs, and sulphate and nitrate concentrations by man's activities. An understanding of these various factors enables the hydrogeologist to unravel the geochemistry of a bottled water and say something about its origin.

Waters derived from upland springs, including those in Cumbria or Dartmoor, have relatively short flow paths and there is little opportunity for water/rock interaction to occur. In consequence, such waters are low in dissolved solids and are often close to rainwater in composition. Waters from limestone terrains generally have high bicarbonate and calcium concentrations and are simply rainwater that has dissolved the host limestone. Elevated nitrate concentrations in such waters show that their source is intensively farmed agricultural land. Waters derived from tuffs and lavas in the Scottish Midland Valley have higher concentrations of magnesium and lower concentrations of bicarbonate. In these areas, rainfall has dissolved aluminosilicate minerals rather than carbonates. Some waters, such as those from Buxton, contain no nitrate suggesting that they have a deep-seated origin. In the East Midlands, the waters at Woodhall Spa contain ammonia and are highly

mineralized, suggesting that they are old groundwaters with a long flowpath and plenty of time for extensive water/rock interaction to occur.

In Britain, bottled water is drunk because it is thought to be better or “safer” to drink than tap water. However, this is not the case in many overseas countries, where bottled water is often consumed because of its medicinal properties. Many of these waters are high in dissolved solids and have diuretic properties. Consequently, British holiday-makers travelling abroad need to be careful to buy bottled waters that are comparable with the water they drink at home, otherwise problems may ensue.

The question posed at the beginning of this summary was whether or not it was worth buying bottled water? Certainly if your local supply is over-chlorinated, or if the water smells musty (because of algae growing in your storage tanks), it is probably worth buying water for drinking or for diluting that after-dinner glass of whisky. However, in most cases the bottled water is unlikely to be any improvement on your local supply, and certainly no safer.

LECTURE

William Smith (1769-1839) and the search for raw materials 1800-1820

Lecture presented to the Society on Saturday 13th December 2003 by Prof. Hugh Torrens of Keele University.

This lecture, recounting Smith’s career as a canal engineer, land and mineral surveyor, cartographer and geologist, was originally presented as the Geological Society’s William Smith Lecture for 2000. As such, it can be read in the Geological Society Special Publication 190 (2001) *The Age of the Earth: from 4004BC to AD2002* (pp. 61-83). It also appears as supplementary material (pp. 153-192) in the Bath Royal Literary and Scientific Institution’s 2003 reprint of John Phillips’ 1844 *Memoirs of William Smith, LL.D.* This reprint, which also includes an *Introduction to the Life and Times of William Smith* especially written by the speaker (pp.xi-xxviii), was published in a limited edition of 600 copies (ISBN 0 9544 9410 5). It is not available from bookshops, but a few copies may still be available at a cost of £15 (+ p & p); enquiries should be directed to the Bath Royal Literary and Scientific Institution, 16 Queen Square, Bath BA1 2HN, or by phoning 01225 312084.

LECTURE

Life and work of Alfred Wegener

Summary of the lecture presented to the Society on Saturday 3rd April 2004 by Dr Clare Dudman, freelance author.

In 1968, J. Tuzo Wilson declared that the recent revolution in geology should be called the Wegenerian revolution in honour of its chief proponent, Alfred Wegener. Yet Alfred Wegener remains little known, in spite of having a surprisingly full life of geographical and scientific discovery.

Alfred Wegener was born in 1880 in Berlin. He was the youngest of five children, two of whom died before adulthood. At eighteen, he entered the Friedrichs-Wilhelms University in Berlin to study science, graduating with highest honours with his dissertation on the astronomical Alfonsine tables. He then joined his older brother Kurt as an assistant at the Prussian Aeronautical Laboratory. His work was to examine the nature of the atmosphere and this led to the brothers staying aloft for 52.5 hours in a hydrogen balloon, which was then a world record.

As a result, Alfred was asked to go on a Danish expedition to Greenland as meteorologist in 1906. The expedition lasted two years, and Wegener helped map the northeast coast, took the first colour photographs on an expedition and took various innovative photographs of arctic mirages and ice. Significant was his expedition to Sabine island, an island off the coast of East Greenland, where he measured the longitude and found that it appeared to be rather more to the west than where it had been recorded about 40 years previously.

On his return to Germany he became a private lecturer in Marburg, on astronomy, meteorology and cosmic physics. In 1908 he gave a lecture at Hamburg and met his future wife Else Köppen in the audience. He then wrote *Thermodynamics of the atmosphere* (1911), in which he explained the now-accepted theory of rain drop formation in temperate latitudes.

At Christmas 1910, he noticed that the coastlines of Africa and South America interlocked, an idea which he at first dismissed, but a few months later was forced to reconsider, when he came across a compendium of fossils which listed the similarity of fossils of the Carboniferous in South Africa and Brazil. Rejecting the established theory of the time of land bridges, Alfred realised that a far better explanation was that the continents had once been joined and then had drifted apart. He was immediately convinced he was correct, and a few months later presented his ideas to the newly formed Frankfurt Geological Society. There was an immediate outcry, but by this time Wegener had already escaped to Greenland again.

In Wegener's 1912-13 expedition to Greenland, he became one of the first people to overwinter on the ice sheet, and the first to cross it from east to west with ponies. After almost losing their lives several times his team was rescued when almost starving to death.

He returned to marry Else in 1913 and then was almost immediately sent out to the trenches of the Great War. He was wounded twice, the last wound ensuring he was unfit for active service, and was also shell-shocked. He used his recuperation to revisit his idea of continental drift and wrote the first edition of *The Origins of the Continents and Ocean*. The rest of the war he spent as an itinerant meteorologist, also doing revolutionary work on meteorite impact craters on the earth and on the moon.

At the end of the war, in December 1918 he at last obtained his first permanent academic post by replacing his father-in-law, Vladimir Köppen, as a professor of meteorology at Hamburg. During his time there, he wrote two further editions of *The Origins of the Continents and Ocean*, incorporating new evidence, and also, with Köppen, wrote *The Climates of the Geological Past*, which showed how the map of the world looked in past geological ages. His books were translated, and so his ideas came to the attention of a wider audience, and caused yet more controversy and ridicule.

In 1924, the family (he now had three daughters) moved to Graz, where he became professor of meteorology and geophysics. Since he had now accumulated more evidence, he wrote the last edition of *The Origins of the Continents and Oceans*, and in 1926 his ideas were ridiculed at a New York meeting of the American Association of Petroleum Geologists. After this, interest in the theory died down and his work was disregarded. Further meteorological work was followed by two expeditions to Greenland (a preliminary in 1929 and the main one in 1930) to establish three scientific stations across the widest part of the ice sheet.

The last expedition was beset by delays. At the end of September Wegener decided to lead a final sledge party to supply the central station. He arrived at the end of October in atrocious conditions. A couple of days later he set off back to the coast with an Inuit companion called Rasmus. It was the last time anyone saw them alive.

The following summer, Wegener's body was found, sewn into his caribou sleeping bag by his Inuit companion and buried in the ice. It was supposed that he had died of heart failure. His Inuit companion was never found.

Following magnetic exploration of the oceanic floor Wegener's idea was revived in the 1950s and 1960s. But instead of the continents behaving like icebergs pushing through a sea of sima, as Wegener had proposed, it was now suggested that the Earth's crust consists of a small number of plates which

constantly move against each other. In this way, Wegener's theory of Continental Drift evolved into the theory of Plate Tectonics.

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Rasmus Villunsen and Alfred Wegener ready to set off from Eismitte in the middle of the Greenland icesheet, in November 1930 - the last time anyone saw them alive. (Photo: Alfred Wegener Polar and Maritime Institute)