GEOBROWSER

Geology at Flanders and Normandy

This year sees both the centennial of the outbreak of World War I and the 70th anniversary of D-Day, but what role, if any, did geology play in those conflicts? In modern warfare, geology and terrain analysis are essential considerations when planning a military campaign (see *Mercian 2000, 65-66*), but this was not always the case. During the 40-day lead-up to World War I there was hardly any time to consider geology, but that did not seem to matter when a good summer ensured almost perfect battlefield conditions in Flanders. By early October, however, heavy rainfalls greatly hindered the movement of supplies and artillery on poorly drained land and an appreciation of ground conditions then became important. Unfortunately, whereas basic geology had been on the syllabus of British military academies during the 19th century, it had been withdrawn from mainstream teaching by the time that war broke out. The British army did not have a professional geologist in place until 1915, and by the end of the war there were just three full-time officer-geologists *(Geol. Soc. Special Publication 362, 2012)*. By contrast, the Germans had some 250–300 geologists, and although these were of relatively low rank, they had the additional advantage of geological information obtained from the libraries and offices of the Belgian towns and cities that they had occupied.

Geological factors began to loom large when the appalling casualties suffered during trench warfare prompted the advent of offensive (and defensive) tunnelling. Tunnelling techniques in association with siege warfare would have been well known, from examples documented in ancient China between 481 and 221 BC, and later in medieval Britain and France, where battlements were typically undermined from tunnels with entrances concealed within trench systems. Although the Germans were the first to tunnel offensively, in 1914, by mid-1916 the British army had about 25,000 trained tunnellers, and whereas most accounts emphasize recruitment from mining communities, the expertise of sewer workers from the Manchester and London areas was also utilised for excavating through heavy clay substrates.

The work of the 'professional' geologists in the British army was mainly concerned with assessment of groundwater supplies and the siting of mine, trench and dugout systems. Some of the world's first detailed geotechnical maps and reports originated during the Passchendaele Offensive of autumn 1917, when an intense artillery bombardment pulverised terrain on poor-draining Tertiary (Palaeogene) clays. In order to predict infantry progress during the anticipated German counter-attack, one report investigated the behaviour of Ypresian clay following shelling to depths up to 5 m, classifying shell holes according to whether they would fill with water from underlying aquifers, be waterlogged by rain, or would be naturally drained by subcropping sands. A further example of best practice was provided by the German positions at Beaumont Hamel (Hawthorne Ridge), where the incorporation of naturally strong chalk outcrops allowed for deep, dry trench systems that were virtually impregnable. On the other hand, the chalk bedrock facilitated excellent undermining conditions for the British, which resulted in a charge of nearly 20 tonnes of ammonal (ammonium nitrate and aluminium powder) being placed beneath the German lines, causing a crater 20 m deep and 55 m wide.

Learning from the lessons of World War I, geological preparations for the D-Day landings on the Normandy beaches were thorough, and here a strong Midlands connection was provided by the work of Quaternary geology expert, Prof. Fred Shotton of Birmingham University. An archive of top secret materials recently rediscovered at the university's Lapworth Museum reveals that preliminary geotechnical investigations were carried out on a Norfolk beach with a geology similar to that of many Normandy beaches. Geological maps of the Normandy coastline were prepared, showing geographical features including rivers and gradients, with numerous notes in red ink (*www.culture24.org.uk*). First-hand information was gained when Shotton flew over northern France in a Mosquito aircraft modified with a glass observation panel in the base of the fuselage, while under his direction clandestine visits were also made to sample Normandy beach sands and other deposits for their geotechnical properties. On one such visit, an auger was accidentally left behind, and so to cover up this potential give-away it was planned to drop augers on every beach between Norway and Biscay; however, it was soon realised that there were not enough augers available to do this. Shotton's involvement continued after the landings, with investigations into water supplies needed for camps in Northern France, the location of new airfields and the likely problems in crossing the Meuse and the Rhine.

Earthquakes illuminated

Remarkable luminous phenomena known as Earthquake lights (EQL's) have been observed before or during earthquakes, and rarely afterwards. They can take the form of spheres or globes of light floating through the air, or flame-like emanations from the ground either seconds or several days before an earthquake. Notable examples were seen in the town of L'Aquila in Italy, seconds before the 2009 earthquake; along the St Lawrence Seaway in Quebec, 11 days before the powerful 1988 earthquake; and about 100 km northwest of San Francisco just before the disastrous 1906 earthquake.

A recent review noted that 85% of EQL's were observed in continental rift environments, either on or near to sub-vertical rift faults or related transform faults (*Seismological Society of America, 2 January 2014)*. Although associated with a range of earthquake

(left) Earthquake lights from Tagish Lake, southern Yukon, Canada, around the 1st of July, probably 1972 or 1973 (exact date unknown). Estimated to be a metre in diameter, the closest orbs slowly drifted up the mountain to join the more distant ones (white arrows) (photo: Jim Conacher).

(right) Tutankhamun's scarab brooch (photo: April Holloway).

magnitudes between M 3.6 and 9.2, some 80% occurred in conjunction with magnitudes greater than 5.0. The authors suggested that EQL's are related to a rapid build-up of stress prior to fault rupture, and to rapid local stress changes during seismic wave propagation. These changes are believed to activate mobile electronic charge carriers, termed 'positive holes', which flow swiftly along the stress gradients until, when reaching the surface, they ionize air molecules producing the observed luminosities. Support for this mechanism comes from eyewitness accounts and security cameras that captured a large number of light flashes during the magnitude 8.0 earthquake at Pisco, Peru, in 2007. Those measurements gave rare information on the origin of EQL flashes, since they coincided with the passage of seismic waves recorded at a nearby university campus.

There are anecdotal stories that animals can sense changes to their environment during the approach of an earthquake, so can we now speculate that ionized air, which cannot be detected by humans if non-luminous, may play a part in this? The United States Geological Survey says a reproducible connection between a specific animal behaviour and the lead-up to a quake has never been made. However, this may simply reflect the obvious difficulties inherent in recognising anomalous animal behaviour, and then linking this to a correlation between detectable ground emanations and seismic wave propagation.

Could it be that EQL's are the explanation behind the biblical story of Moses and the burning bush? For example, Exodus Chapter 3 relates that on Mt. Horeb (sometimes referred to as Mt. Sinai)*: "...the angel of the Lord appeared to him in flames of fire from within a bush. Moses saw that though the bush was on fire it did not burn up. So Moses thought, 'I will go over and see this strange sight—why the bush does not burn up."* We know that during their flight from Egypt Moses and the Israelites must have crossed two intense earthquake zones, the Red Sea Rift and, farther east, the Dead Sea Transform fault system (*see Mercian for 2004, 48-50*). Although the precise location of Mt. Horeb is currently disputed (and the site of the burning bush is claimed by St Catherine's Monastery in central Sinai), many scholars place both it and the region of Midian, where the burning bush encounter is now thought to have taken place, on the eastern side of the Gulf of Aqaba (*Red Sea crossing: accordingtotheScriptures.org)*. That seaway coincides with the southern sector of the Dead Sea Transform, perhaps suggesting that Moses may have either observed an EQL, or somehow utilised local folklore about them. Other biblical stories may have been inspired by seismic phenomena: for example, the partial destruction of Jericho (*Joshua, Ch. 6*), is commonly attributed to a severe earthquake farther along the fault, rather than simply to loud trumpeting.

Comets and pharaohs

A link between ancient religious beliefs and cosmology is evoked by the large specimen of polished yellow-brown glass in the striking scarab centrepiece to Tutankhamun's brooch. The glass could only have come from a strewnfield in the Libyan Desert, where a large area of silica-rich sand was fused by the impact of a comet that entered the Earth's atmosphere 28.5 million years ago. An unusual black pebble recently found at the strewnfield provides further evidence for an extra-terrestrial origin: it has a carbonaceous composition, with microscopic diamonds, and carbon isotopes that are consistent with values obtained for interplanetary dust (*Earth and Planetary Science Letters 2013, v 382, 21-31)*. The investigators concluded that the pebble is a fragment of a cometary nucleus, and as such it constitutes the first ever ground-based evidence provided by a comet exploding in the atmosphere. Further confirmation of this may arrive later this year, if the *Rosetta* mission is successful in analysing the surface of an actual comet. The black pebble was named "Hypatia" in honour of the Greek female mathematician, astronomer and philosopher, Hypatia of Alexandria, a controversial figure who was murdered by a Christian mob in AD415.

Tutankhamun's brooch shows that the glass debris of the strewnfield clearly attracted human attention, and was possibly symbolic in the religious sense. If so, the ancients may unwittingly have chosen a material compatible with their theology based on sky-worship. This included a belief in the sun-disc, known as Aten, which was deified by Tutankhamun's father (although not by Tutankhamun himself). Another cosmological manifestation lies in the internal construction of the great pyramids, which have corridors linking the burial chamber to the sky so that the deceased pharaoh and entourage could spend the rest of their after-life traversing the heavens.