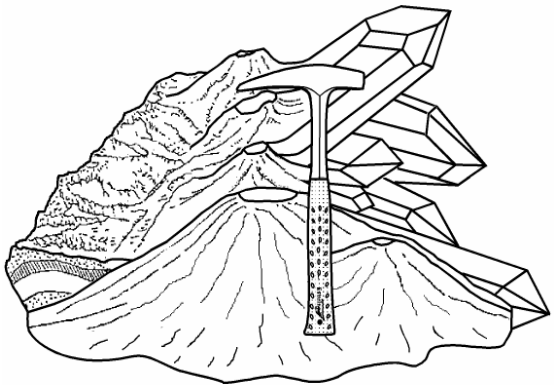


Geocene

Auckland GeoClub Magazine
Number 5, December 2009

Editors: Hugh Grenfell and Helen Holzer

CONTENTS

AN ORIGIN FOR BAKER'S BEAN, ACACIA BAY, TAUPO: SLUMPING AND WATER EXPULSION DURING RAPID LAKE LEVEL FALL	**Bruce Hayward**	**1-2**
BRYOZOANS AND OTHER FOSSILS FROM THE HOKIANGA REGION, NORTHLAND.	**Seabourne Rust**	**3**
AHIPARA ANCIENT KAURI FOREST	**Peter Stewart**	**4-5**
SOME ENIGMATIC MICROFOSSILS	**Hugh Grenfell**	**6-7**
OVERTURNED PAHOEHOE LAVA FLOW LOBES, WHITES BEACH, WAITAKERE RANGES	**Bruce Hayward**	**8-9**
ST KENTIGERNS SECTION, PAKURANGA FOSSIL LEAVES – A SHORT NOTE	**Hugh Grenfell**	**10**
CONTROVERSIAL ASCOT LAVA CAVES OLD AND NEW	**Jill Kenny**	**11-14**
THE LOST JETTIES	**Margaret Morley**	**15-16**
McLAUGHLIN'S VOLCANO (MATUKUTUREIA) TUFF RING AND MOAT REMNANTS	**Bruce Hayward**	**17**
FILKSONG HANDBOOK	**Jon Kay**	**18-20**
COSMOS CARTOONS	**Jon Kay**	**21-22**
GEOPUZZLES	**Rhiannon Daymond-King**	**23-27**

AN ORIGIN FOR BAKER'S BEAN, ACACIA BAY, TAUPO: SLUMPING AND WATER EXPULSION DURING RAPID LAKE LEVEL FALL

Bruce Hayward

In April 2009, 24 GeoClub members spent a weekend looking at the geology around Taupo. Dr Jill Jolly from GNS showed us around a number of striking localities. On Acacia Bay Rd we were looking at the spectacular beach deposits that developed on top of Taupo ignimbrite after its 1800 yr BP eruption. Murray Baker suggested we drive around the corner to see an interesting road cut exposure he had previously seen of a large block "floating" in the Taupo Ignimbrite. The block had a bean shape and we soon adopted the informal name "Baker's Bean" for it.



Fig. 1. Murray Baker and "Baker's bean" floating in Taupo Ignimbrite on Acacia Bay Rd.

The road cutting is on the west side of the Acacia Bay Rd to Whakamoenga Pt where the road swings over Te Ruatakuahi Pt (U18/731711). The 30 m long by 3 m high cutting exposes the upper part of pumice-rich Taupo ignimbrite, erupted from the final phase of the 1800 yr BP Taupo eruption (Rosenberg and Kilgour, 2004). In the upper part of the cutting and in most places overlying the ignimbrite is a disrupted, bedded sequence of pumice and ash beds up to 1 m thick. The basal 0.2-0.5 m of this sequence contains well-sorted, pumice lapilli and coarse sand beds with lensing, cross-bedding and ripples that nearby have been interpreted by Manville (2001) to be beach deposits that accumulated on the edge of Lake Taupo 5-10 years after the 1800 yr BP eruption as the lake was filling to a maximum height 34 m above present. The lake apparently remained at this height for some years before the blockage near the town of Taupo was breached and a major breakout flood lasting just a few days rapidly lowered the lake to a level within a few metres of the present.

In this exposure the lake sediment occurs as a number of 1-8 m long blocks separated by 0.5-2 m wide gaps filled with ignimbrite (Fig. 2). The edges of a number of the blocks are folded upwards, in several instances to nearly vertical. "Baker's bean" is of the same bedded composition as the overlying beach and lake floor deposits but has been folded through 180 degrees at each end to form an elongate roll that is oval in cross-section. Many of the features in this road cutting are similar to those seen on a smaller scale and produced by water expulsion in Waitemata Sandstones around Auckland.



Fig. 2. Ignimbrite material separating two blocks of beach and lake sediment inferred to have resulted from water expulsion along cracks between the blocks.

A number of hypotheses were considered for the origin of the features. The most likely was that the beach and lake floor sediment blocks had been formed by water expulsion from the ignimbrite breaking through the thin overlying sequence and while flowing upwards and out the water carried some of the unwelded ignimbrite with it and had also folded up the edges of the sediment blocks. "Baker's bean" may be an extreme end-member of this process where so much of the underlying ignimbrite had flowed out that a block of the sediment settled down into the ignimbrite and the flowing watery mix around it folded both ends over into a roll. The upwards flow of ignimbrite material at this point created a mound above the "bean"



Fig. 3. Rounded mound of ignimbrite is inferred to have flowed up over "Baker's bean" and in the process folded it over onto itself from both sides.

I hypothesise that this episode of water expulsion and disruption may have occurred as the lake level dropped rapidly. While the lake level was high the underlying ignimbrite and pumice beds would have been fully saturated with water. While the lake level was dropping rapidly the sloping sequence may have become unstable and slumped slightly down slope

creating slope-parallel cracks in the overlying beach and lake sediment unit. Water within the more porous ignimbrite and underlying Plinian pumice unit was confined by the ash-rich horizons in the overlying lake beds (aquaclude). As the lake water above the sequence dropped away, the water in the underlying ignimbrite was unsupported and was expelled out through the cracks, expanding them and carrying loose ignimbrite with it.

References:

Manville, V., 2001. Field Trip FT2. Environmental impacts of large-scale explosive rhyolitic eruptions in the central North Island. Geological Society of New Zealand Miscellaneous Publication 110C, 19 pp.

Rosenberg, M. and Kilgour, G., 2004. Field Trip 1. Taupo Volcano. Geological Society of New Zealand Miscellaneous Publication 117B, 10 pp.

BRYOZOANS AND OTHER FOSSILS FROM THE HOKIANGA REGION, NORTHLAND.

Seabourne Rust

Since completing my PhD thesis (Plio-Pleistocene Bryozoan Faunas of the Wanganui Basin, New Zealand: diversity, distribution and paleoecology. University of Auckland, 2009), I have been taking a break from academia, and have been focusing on my art (have yet to paint a bryozoan, but we'll see!). However work continues preparing Wanganui thesis material for publication (with Dennis Gordon of NIWA). I have been living up in the wilds of Hokianga, Northland, and have been investigating local occurrences of fossil bryozoans and other macrofauna, with my partner Diane. We are currently doing fieldwork and researching localities in the isolated Taita Valley, where Miocene deposits of the Otaua Group are in places known to contain a regionally significant mollusc fauna (e.g. Laws 1947, 1948; Wakefield 1977; Evans 1994; J.Grant-Mackie pers.comm.). Bryozoans are common in shelly grit horizons of the Waitiiti Formation, which also bear some of New Zealand's largest foraminifera. We found one discoidal specimen with a test 25 mm across, that had been encrusted by a bryozoan colony! Although yet to be studied in detail, there appears to be a diverse bryozoan assemblage in the unit, with both encrusting and erect colony fragments present. Of particular interest to myself are a number of rounded calcareous mudstone cobbles and boulders in the bed of the Taita Stream that show dramatic evidence of multiple-reworking. They represent Late Cretaceous concretions (some contain fragments of the bivalve *Inoceramus*), that have been exposed on the shallow sea floor during the Miocene, during which time they were worn, bioeroded and encrusted by bryozoans, serpulid tubeworms, oysters, corals and other epifauna. These are still preserved today on rocks now weathered out and occurring in the bed of a mountain stream! Some photos shown below. We hope to continue our investigation next summer and soon provide a taxonomic list of fossil bryozoans. I can be contacted at: seabourne.rust@gmail.com

A preliminary list of Bryozoan taxa recorded from the Waitiiti Formation (Otaian Stage, Miocene), Taita Stream, Waimamaku, South Hokianga, Northland, New Zealand (NZ Fossil Record File No. O06/f0121).

Fossil specimens were collected by S. Rust and D. R. Yanakopulos (2008-2009), identified by S. Rust, September 2009. The number of Bryozoa identified here (21 cheilostomes + 7 cyclostomes = 28 taxa) is only a minimum, somewhat limited by preservation; diversity is expected to increase with future collection and use of SEM to distinguish species.

Order CHEILOSTOMATA
Aimulosia marsupium EN
Akatopora circumsaepta EN
? *Arachnopusia unicornis* EN
Bitectipora cincta EN
Cellaria immersa ER
Celleporaria agglutinans EN
Chaperia sp. EN
Chaperiopsis sp. EN
Crassimarginatella sp. EN*
Escharella cf. *spinosissima* EN*
Exochella cf. *conjuncta* EN
Figularia sp. EN*
? *Foveolaria* sp. ER
Galeopsis adherens EN
Galeopsis polyporus ER
Hippomenella vellicata EN
Macropora sp. EN*
? *Onychocella* sp. EN
? *Schizoporella* sp. EN*
? *Steginoporella* sp. ER
indet. fenestrate spp. ER

Order CYCLOSTOMATA
Attinopora zelandica ER
Crisina cf. *hochstetteriana* ER
Desmediaperoecia biduplicata EN*
Diastopora sp. EN*
Disporella sp. EN*
Telopora lobata ER
Tubuliporine indet. '*Hastingsia*-like' sp. EN

EN = encrusting colony (occur mostly on shell fragments, pebbles and rhodoliths);
ER = part of erect colony;
* = at least one colony recorded here encrusting the large foraminifera *Lepidocyclina (Nephrolepidina) orakeiensis*.



AHIPARA ANCIENT KAURI FOREST
Peter Stewart

I first learned of the Far North's fossil kauri forests on a tourist bus trip to Cape Reinga and Ninety Mile beach. The bus stopped at the Ancient Kauri Kingdom north of Kaitaia to be washed down to remove sand and salt, and let the tourists visit the shop and cafeteria. The Kauri Kingdom uses fossil swamp kauri from near Ahipara. I bought a small unfinished bowl made of the kauri and decided that I needed to learn more. Recently, I went north again and met up with clansman Dave Stewart, who drove me to the fossil kauri site and discussed his ideas on the formation of the fossil forest (see also the Ancient Kauri website referenced below).

There are various theories as to how the trees were preserved - tsunamis, volcanic shock waves, meteor strike, hurricanes and so on. All these theories would suggest that the trees would be lying in the ground oriented in the same general direction.

Dave Stewart has discovered that there are three layers of logs lying on top of each other in a criss-crossed fashion, suggesting that the trees fell over randomly. Some trees also died standing up, and decayed to ground level, leaving only the root structure preserved. These trees grew over the top of fallen horizontal logs in the ground. Each layer probably represents a different generation because in each the trees are mature (600 years or more old). The deposit is more than 45,000 years old, but the age difference between the top layer of logs and the bottom layer is probably only about 2000 years.



Figure 1: Dave Stewart, standing alongside an excavated Kauri.

The buried forest is located just inland from the present coast. Over tens of thousands of years, sand was blown inland forming hollows and dunes. Kauri forests became established over the area. The hollows would have in time turned into ponds, lakes and swamps once an impervious base formed. The large size and shallow rooting systems of the kauri, the looseness of the soil, and rising water levels, made the trees unstable. During various storms it would not take much to make these giants fall over into the wetland hence the criss-cross pattern as they fell at different angles all around the edge of the wetlands. As the next kauri forest regenerated and trees reached full size they too became unstable and fell over. This process repeated itself over hundreds of years with other decaying vegetation meanwhile forming the peat that the trees are buried in.



Figure 2: Excavating a log (AKK photo).

The logs are buried just beneath the surface of the ground. And only the lower trunk section and ball root structure is usually found. The trunks tend to taper to a V shape as the portion of the log lying above ground has decayed to ground level. Some logs are inclined at 20^0 into the ground, suggesting that they have been pushed into the soft ground with some force, probably by a larger tree that has fallen onto them. For this reason occasional complete round logs are found lying deeper in the ground.



Figure 3: Soil profile at extraction site.

There are other strange features concerning the logs. Most of the recovered trunks have the heartwood off-centre, i.e. the core is not in the middle of the trunk. Apparently the branch stumps favour the wider side of the log, where the annular growth rings are farther apart. However, tests indicate the timber to be denser in this area, contrary to expectations. I speculate the side of the tree facing towards the water

would be less restricted as far as sunlight, space etc than that facing inwards towards the bush. Maybe the cell structure and compacting of the growth rings would explain the less dense timber in this area.



Figure 4: Fossil kauri trunk made into a staircase at the Ancient Kauri Kingdom (girth: 11.3 m, diameter: 3.6 m, growth: 1,087 years).

The material for this article was obtained, with permission, from David Stewart at the Ancient Kauri Kingdom Ltd, Awanui. The photographs are mine unless they have AKK in the caption.

Some notes on radiocarbon dating:
Carbon has two common stable isotopes, ^{12}C and ^{13}C. The "rare" unstable isotope ^{14}C, used as a dating tool, is produced in the upper atmosphere when cosmic ray neutrons impact nitrogen atoms. A proton is removed producing ^{14}C which rapidly combines with oxygen to form carbon dioxide.

$$^{14}N + n \Rightarrow {}^{14}C + p$$

where n is a neutron and p is a proton.

In marine and terrestrial ecosystems this carbon dioxide, is assimilated by plants through the process of photosynthesis and then into animals through the food chain.

Because ^{14}C is unstable and decays by losing an electron back to nitrogen at a known rate it can be used as a radiometric clock.

$$\text{Decay of } {}^{14}C \Rightarrow {}^{14}N + ß$$

$ß$ = a weak beta particle or electron

In the 1940s a team of scientists led by Willard Libby (University of Chicago) succeeded in discovering the "half life" of ^{14}C. They found that after death (of a bivalve, for example) half of the ^{14}C remaining in a given sample of carbon (in this case the ^{14}C in the calcium carbonate of the shell) would disappear in 5568 years. The decay continues logarithmically so that in another 5568 years another half of the remaining ^{14}C would decay, and so on, until after about 10 half- lives no more ^{14}C would remain. The half life of ^{14}C and the ratio of stable to unstable C isotopes remaining in a given sample are used to calculate an age. The "limit" of radiocarbon dating is between 50-60,000 years.

There are two radiocarbon dating laboratories in New Zealand; the Waikato Radiocarbon Dating Laboratory at the University of Waikato , and the Rafter Radiocarbon Laboratory at GNS Science, Wellington.
For more information visit the Waikato Radiocarbon Laboratory and Wikipedia websites listed below.

Photographs: by P. Stewart except for figure 2 (Ancient Kauri Kingdom, D Stewart).

References:
Ancient Kauri Kingdom website
www.ancientkauri.co.nz

Radiocarbon web-info (Waikato University and the University of Oxford)
http://c14.arch.ox.ac.uk/embed.php?File=webinfo.html

Wikipedia Radiocarbon dating
http://en.wikipedia.org/wiki/Radiocarbon_dating

SOME ENIGMATIC MICROFOSSILS
Hugh Grenfell

In the course of our foraminiferal research we were often finding in our samples curious, (0.1-0.2mm) spheroidal microfossils (Figures 1-5). We have found them in Recent, Holocene and Pleistocene sediments (often estuarine) from a number of localities. They are non-calcareous (we assumed siliceous) and hollow (when viewed wet) with a tiny external depression (see Figure 4a). When imaged using the scanning electron microscope they have a very distinctive surface sculpture (which is often eroded) and interior structure. Figures 1-2 illustrate a "Species A" with a stellate micro-sculpture; figure 1 being less well preserved or eroded. Figures 3a-c of a broken specimen illustrates the wonderful radiating, hexagonal tubular structure of the interior. You can also see the same structures in the transmitted light image (Figure 5).The tubes do not open to the surface.

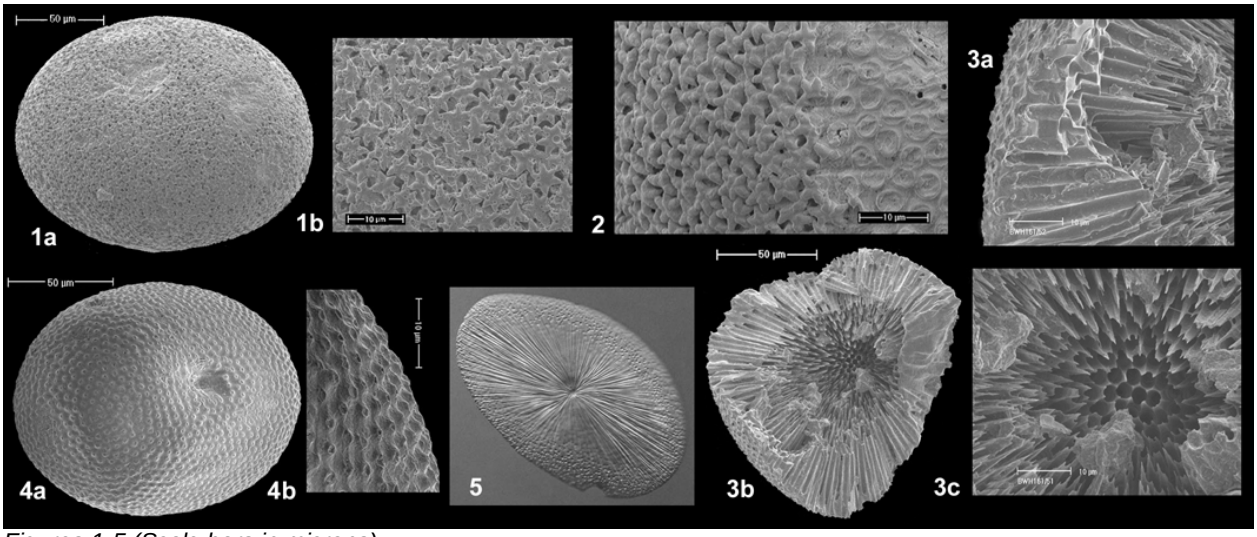
Because the microfossils were sometimes quite common it was frustrating not knowing what they represented or what they might tell us. This began a search through the literature, the internet and the sending of images to colleagues to see if they had any clues. Groups considered included radiolarians, discoasters, diatoms, foraminifera, phytoliths, palynomorphs and sponges. Most of the above were relatively easily ruled out for one reason or another leaving possibly sponges. Sponges produce a range of siliceous spicules but what were these?

The answer was eventually forthcoming through an internet group for sponge specialists. These microscopic siliceous spheres were sterraster microscleres characteristic of a small marine sponge family, the Geodiidae. In New Zealand only five species are recorded today (Kelly et al 2009).

Sterrasters are always present in the geodiids forming a superficial ectosomal crust (Figure 6) giving the sponges a characteristically tough, leathery feel. As can be seen from Figure 6 a single sponge contains thousands, if not millions, of sterrasters.

Geodiid sponges first appeared in the Palaeozoic but their fossil record in New Zealand is limited to the Cenozoic (Kelly et al. 2009). They have been recorded from the early Runangan (Late Eocene) part of the Oamaru Diatomite (Hinde & Holmes 1892; Rich 1958) and from the shallow marine Kapitean to Haweran (Late Miocene to Late Pleistocene) strata of the Whanganui Basin (Turner 1944; Rich 1958; Te Punga 1954, 1964).

So, it was nice to know the sterrasters represented a quite specific type of sponge but the next problem was that records of the Geodiidae in New Zealand today (and most records globally) are from deep water habitats (Kelly et al. 2009). So why were we finding them in modern and fossil shallow water environments? One answer is because of their small size, abundance, shape and robust construction these microfossils are easily reworked from older deepwater sediments (e.g. Tertiary bathyal mudstones) into younger deposits. Reworking is quite likely but some of our material is extremely well preserved suggesting a more recent local source.



Figures 1-5 (Scale bars in microns).
1a-b. "Species A", BWH 161/48, Core A9, 72-74cm, Ahuriri Lagoon, Napier.
2. "Species A", BWH 163/54, Core PI2, 14-16cm, Manukau Hbr.
3a-c. "Species A", BWH 161/47, Core A9, 72-74cm, Ahuriri Lagoon, Napier.
4a-b. "Species B", BWH 163/39, Core PK04-1, 120-121cm, Hawkes Bay.
5. Transmitted light image (DIC), 40X objective, courtesy of Wim van Egmond, age and locality unknown.

.

One possibility is that we don't know enough about our shallow water sponges and that the Geodiidae are actually present in our harbours and estuaries. There is some evidence for this possibility overseas. They are known from lagoonal environments in southern Italy in water as shallow as 0.5m where both sessile and non-sessile forms of *Geodia cydonium* are found (Mercurio et al. 2006).

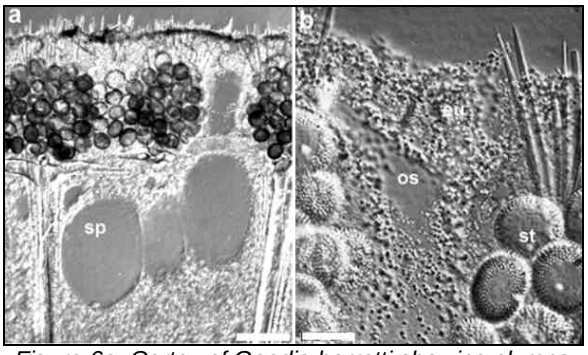


Figure 6a. Cortex of Geodia barretti showing clumps of sterrasters near the outer surface of the sponge. 6b close up of same (from Hoffmann et al. (2003).

In conclusion, while the mystery has been solved and the origin of these microfossils narrowed down to a particular family of living sponges we remain in the dark as to their palaeoenvironmental usefulness. If you find them fossil they might be reworked; and if they are not, do they mean the sediment was deposited in deep or shallow water? We need to know much more about our living Geodiidae to get habitat information such as water depth, turbidity, salinity, temperature, substrate, current speeds and so on. Do they have any biostratigraphic potential? My feeling is probably not much. I have seen Eocene material from Canada (Frank Thomas pers comm.) which is very similar to "Species A" (Figures 1-2) suggesting these sterraster morphologies are extremely conservative. However further study may well prove me wrong!

References:

Hinde, G. J.; Holmes, W. M. 1892: On the sponge remains in the Lower Tertiary strata near Oamaru, Otago, New Zealand. Linnean Journal of Zoology 24: 177–262.

Hoffmann et al 2003: Growth and regeneration in cultivated fragments of the boreal deep water sponge Geodia barretti Bowerbank, 1858 (Geodiidae, Tetractinellida, Demospongiae). Journal of Biotechnology 100 (2): 109-118

Kelly, M. et al. 2009: Phylum Porifera In: New Zealand Inventory of Biodiversity (Volume 1)*, (ed) D.P. Gordon, Canterbury University Press. Pp. 23-46.*

Mercurio, M et al. 2005: Sessile and non-sessile morphs of Geodia cydonium (Jameson) (Porifera, Demospongiae) in two semi-enclosed Mediterranean bays. Marine Biology 148: 489–501.

Rich C.C. 1958: Occurrence of sterrasters of the Geodiidae (Demospongea, Choristida) in late Cenozoic strata of western Wellington Province, New Zealand. New Zealand Journal of Geology and Geophysics 1:641-646.

Te Punga, M. T. 1954: Fossiliferous late-Pleistocene beds in a well at Awahuri, near Palmerston North. New Zealand Journal of Science and Technology B36: 82–92.

Te Punga, M. T. 1964: Some geological features of the Otaki-Waikanae district. New Zealand Journal of Geology and Geophysics 5: 517–530.

OVERTURNED PAHOEHOE LAVA FLOW LOBES, WHITES BEACH, WAITAKERE RANGES

Bruce Hayward

In September 2009 a small, select group of GeoClubbers parked their cars in the cloud on Anawhata Rd and headed down the track between Whites Beach and Paikea Bay, past the site of the burned down University hut and down to the foreshore of Fishermens Rock Pt. Here we examined the contact between monolithologic (=one rock type), partly red-oxidised, angular andesitic breccia and the heterolithologic (many rock types), subrounded cobble pebble Piha Conglomerate. We speculated and hypothesised about the nature of this near-vertical contact and what its relationship might be to the 100 m + thick pile of lava flows and oxidised breccias that form the cliffs around Paikea Bay to the north and behind Whites Beach to the south.

Previously I have inferred that this was the near vertical wall of an ancient early Miocene crater that was filled with lava flows and autobrecciated flows that were partly oxidised red as they erupted subaerially (e.g. Hayward, 1977, 1983). The Piha Conglomerate country rock had accumulated on the submarine slopes of the Waitakere Volcano about 21-18 myrs ago and following regional uplift, a line of volcanic vents along the west side of the present-day Waitakere Ranges began erupting subaerially (Hayward, 1979, 2009). The Whites Beach crater was one of these eruptive centres and was very similar in form to others at Taranaki Bay (Whatipu) and O'Neills Beach (Te Henga).

Later we climbed back up the ridge and dropped down into Whites Beach. The continued build-up of sand in this bay suggests that it will not be too long before people can walk around from Anawhata to Whites Beach and North Piha on the sand at low tide, without having to climb up and over the intervening Te Waha and Fishermens Rock points.

In the southwest corner of Whites Beach, close to high tide level today, we examined a 10 m wide, 20 m high exposure of andesite rock The rock was cut by numerous wavy fractures all tilted at about 70 degrees to the west. Closer examination indicated that between the fractures the lava occurred in lobe-like swellings with their east sides generally more convex than their west. With a little bit of imagination and by turning ourselves almost upside down we could recognise that this andesite had accumulated in layers, each 10-50 cm thick and the fractures were the contacts between the layers. Each layer had swelled lobes with convex upper surfaces separated by thinner portions.

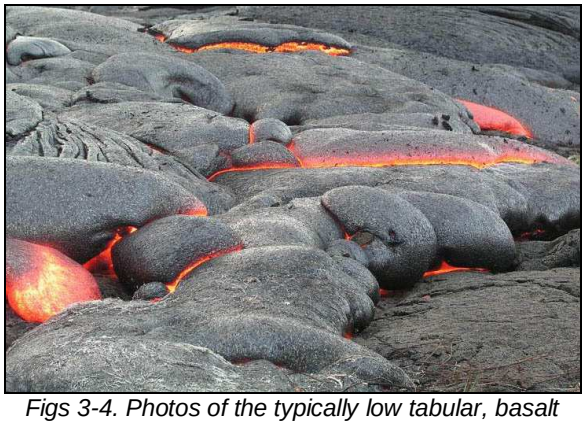




Figs 1-2. GeoClubbers examine the overturned (70 degree tilted) layers of early Miocene pahoehoe andesite lobes at Whites Beach, Waitakere Ranges.

Their appearance is very similar to pahoehoe lobes that sometimes form in subaerial basalt lava flows on Kilauea, Hawaii





Figs 3-4. Photos of the typically low tabular, basalt pahoehoe lobes with convex upper surfaces erupted in recent times in Hawaii. [Both from http://hvo.wr.usgs.gov]

The Whites Beach pahoehoe lobes occur in a distinct block that is now upside-down with a 70 degree tilt. Examination of the adjacent cliff to the west suggests that this block is part of an early Miocene slump of material that lines the inside of the inferred crater wall. Piha Conglomerate country rock outcrops on Te Waha Pt to the west and crater-filling flows outcrop in the cliffs of Whites Beach to the northeast. I infer that the pahoehoe flow lobes were erupted onto the surface close to the edge of the crater and some distance above where they now lie. Possibly lava withdrawal inside the vent's throat caused the contents of the crater to partly collapse downwards triggering a slide of material and blocks (including the pahoehoe lava) down inside the crater wall.

Superficially these pahoehoe lobes resemble pillow lava, but they do not have the thick, chilled, glassy selvedge of submarine lava pillows nor are they circular or subcircular in cross-section. Their rather flattened tabular cross-section helps identify them as subaerial rather than submarine in origin, as does their association with red-oxidised rocks that were clearly erupted in air. This is the only occurrence of pre-Quaternary pahoehoe lobes of this kind that I know of in northern New Zealand.

References:

Hayward, B. W. 1977: Miocene volcanic centres of the Waitakere Ranges, North Auckland, New Zealand. Journal of the Royal Society of New Zealand 7: 123-141.

Hayward, B. W. 1979: Ancient undersea volcanoes: A guide to the geological formations at Muriwai, west Auckland, Geological Society of New Zealand Guidebook 3. 32 p.

Hayward, B. W. 1983: Sheet Q11 Waitakere. Geological Map of New Zealand. Wellington, DSIR.

Hayward, B. W. 2009: Land, sea and sky. In: F. MacDonald and R. Kerr (eds). West - The history of Waitakere. Randon House. Auckland. Pp. 7-22

ST KENTIGERNS SECTION, PAKURANGA FOSSIL LEAVES – A SHORT NOTE

Hugh Grenfell

Some pictures taken by M. Morley of fossil leaves from the St Kentigerns section beside the Tamaki Estuary, Pakuranga (R11/772756) piqued my interest later when I read a paper by Pearce et al. (2008). The paper investigated mid-Pleistocene, Mangakino Volcanic Centre derived silicic tephras in the Auckland region including the St Kentigerns section. In 2009 I revisited the outcrop to investigate how the leaves were preserved and took more pictures.

Pearce et al (2008) describe a 5m thick section (Figure 1) of mottled inorganic clay loam to clays which paraconformably overlies a sequence of nine discrete mm–dm thick silicic tephras (labeled AT-86, AT-22 to AT-29). The tephras are interbedded with mottled clays (upper) and woody carbonaceous muds / peat with in situ tree stumps (lower). They considered the tephras to be a mixture, with some representing reworked material and others (e.g. AT29, AT27/28) being primary airfall.

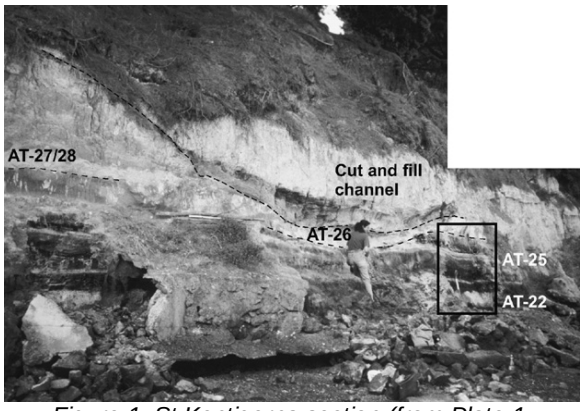


Figure 1: St Kentigerns section (from Plate 1, Pearce et al. 2008)

Bed AT26 (see Figure 1) contains various plant fossils but those illustrated by Pearce et al. (Figure 2A, 2008) were the most interesting because of their preservation (Figure 2 here). Incorrectly identified as pohutukawa by Pierce et al. (2008) the leaves belong to taraire (*Beilschmiedia tarairi*) (E. Cameron, Auckland War Memorial Museum pers comm.). More taraire leaves were later observed in AT26 and these are also illustrated here (Figure 3). The leaves are well preserved but very fragile and in extremely friable sands.

The attitude of the leaves, best seen in Figure 2, is interesting since rather than lying flat and parallel to bedding they are upright looking as if they were dipped into a liquid slurry which then set holding them in place. They also appear to be in clusters attached to the same stem. Layering within the bed can be convoluted (Figure 2) and it is probable that the water saturated, reworked tephra was easily disturbed soon after deposition. Just how the leaves came to have their attitude within the bed is difficult to understand.

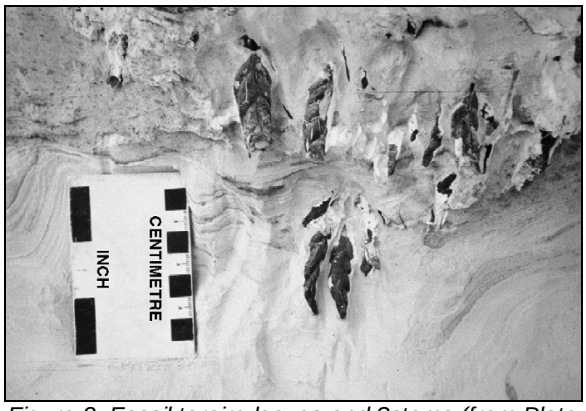


Figure 2: Fossil taraire leaves and ?stems (from Plate 2A, Pearce et al 2008).



Figure 3: Close up of taraire leaves and laminations.

Was a variety of plant material including stems with taraire leaves carried along, perhaps "floating" in a slurry, which "froze" them in position when the material came to rest? This doesn't explain why the leaves are preserved "across" parallel or convoluted laminations. Maybe they become "fixed" in a given lamination and the other laminations simply filled in around them later. Alternatively did the leaves gradually sink into a lower density, laminated, water saturated sediment without disturbing the laminations? Whatever the explanation the presence and mode of preservation of the leaves supports the notion proposed in Pearce et al. (2008) that AT26 and some of the other tephras here do not have a primary airfall origin but are reworked by water in a fluvial or lacustrine environment.

Reference:

Pearce, N.J.G., Alloway, B.V. and Westgate, J.A. 2008: Mid-Pleistocene silicic tephra beds in the Auckland region, New Zealand: Their correlation and origins based on the trace element analyses of single glass shards. Quaternary International 178 (2008) 16–43.

CONTROVERSIAL ASCOT LAVA CAVES OLD AND NEW

Jill Kenny

The Transactions of the Royal Society of New Zealand in August 1875 records the discovery of moa remains at Ellerslie Racecourse (Cheeseman 1875). The article states that Mr Cheeseman explored a lava cave at Ellerslie and described it as "*….. the whole length of the two unequal compartments into which it was divided being 98 feet, and its height in no place exceeding 8 feet, the floor being composed of basaltic lava. The Moa bones, all more or less decayed, were found only in the smaller compartment.*"

Cheeseman added that "…..*some time ago Dr Alder Fisher informed him that he had seen Moa bones in a small cave near the Ellerslie racecourse, and at his request he had made an exploration of the cave in question. A considerable number of Moa bones were obtained, but in such a bad state of preservation as to be useless for scientific purposes. Hardly any perfect examples were seen. Human bones were found in the same cave, and a considerable number in an adjacent one, but were evidently much more recent than those of the Moa.*"

The approximate location for this archaeological site (R11/61) was suggested by Clough (2004), to be in the eastern corner of the racecourse near Ladies Mile and the steeplechase course. It is recorded as having been destroyed, presumably during landscaping for the racecourse. A recent internet posting (Ellerslie Residents 2008a) suggests a geophysicist has found the probable location of a cave here. This location is, however, in Waitemata Group sediments at the base of the hill near Peach Parade. It is on the western side of a ridge forming the drainage divide between the Waitemata and Manukau catchments, with drained swamp sediments abutting it (Kermode 1992). There is no lava in this vicinity (Figure 1, letter A), and extensive searching and subsurface testing by the Auckland City Council in 2005 has failed to find anything (Glucina 2009). This area has become an emotional topic because of rezoning proposals in the Auckland City Council District Plan. Earthworks in 2008 for the installation of a new stormwater pipe were photographed by an unnamed rezoning opponent and some scoundrel has drawn a fictional diagram with basalt making up the Ladies Mile ridge, overlying tuff and lots of question marks (Figure 2). The photograph, however, clearly shows that earthworks encountered only what should have been expected – weathered Waitemata Group sedimentary rocks.

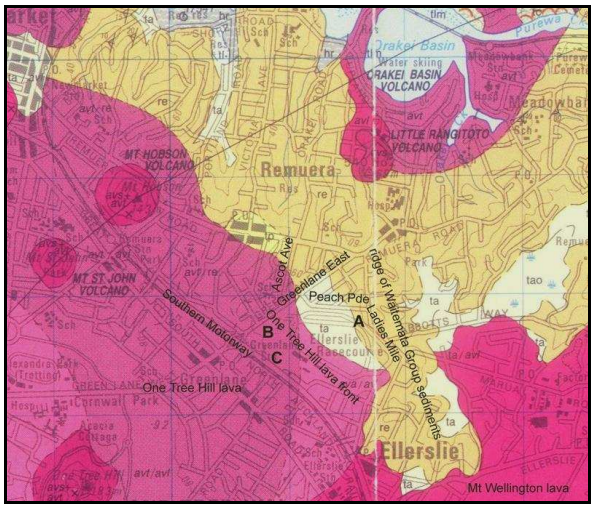


Figure 1. Part of the Auckland geology map (Kermode 1992) covering the Greenlane-Ellerslie area. A = approximate location for this archaeological site (R11/61), B = Ascot Hospital site, C = Ellerslie Racecourse carpark alongside Southern Motorway. Areas coloured shades of maroon are lava flows and tuff, beige areas are Waitemata Group sediments, and pale yellow at Ellerslie Racecourse is drained swamp. The swamp developed when lava from One Tree Hill volcano dammed streams flowing south from Remuera ridge.

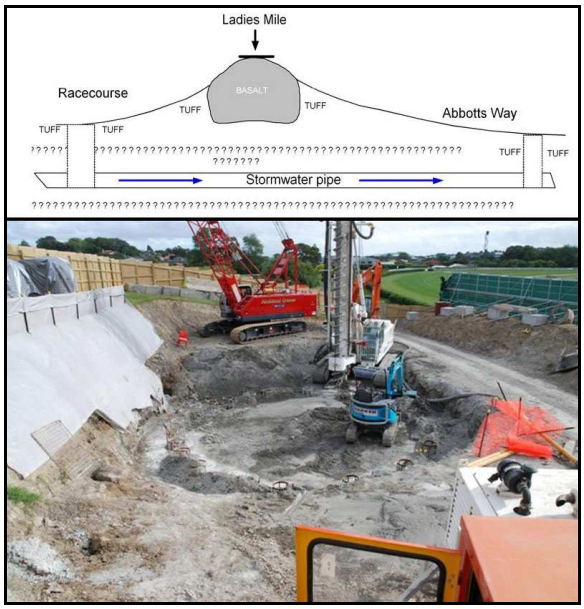


Figure 2. Fabricated cross-section found in a website of Ellerslie Residents (2008b) of Ladies Mile ridge, drawn by opponents of the Auckland City Council's plans for development of the northeastern sector of Ellerslie Racecourse. It was accompanied by a photograph of drainage earthworks in that sector. The grey material is concrete with weathered Waitemata Group sediments visible in the background. There is no basalt or tuff.

It is more likely that the 19thC descriptions referred to "the hill" on the opposite side of the racecourse. This slight rise is the edge of a lava flow originating from One Tree Hill that can be traced from the corner of Mitchelson Street near the motorway bridge to the rise in the roads just

north and east of the intersection of Greenlane East and Ascot Ave (Figure 1). In my opinion, this is the most likely place for a cave with Cheeseman's "floor being composed of basaltic lava" to have existed in the past. The area has been heavily manicured over many decades to beautify the racecourse surroundings and the cave entrance would probably have been filled early in this process.

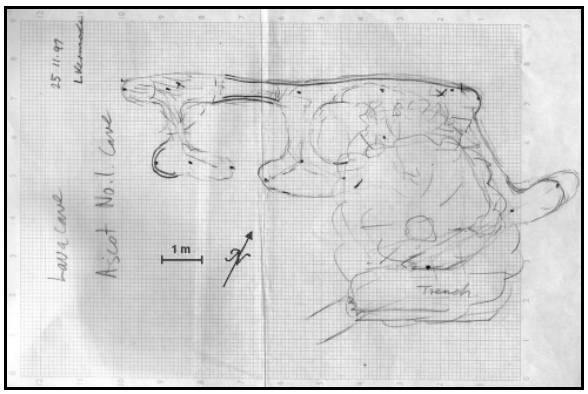


Figure 3.Les Kermode's interpretation of Ascot No.1 Cave (plan view), sketched on 25th November 1997. North arrow and scale bar added.

In 1997 excavations for the Ascot Hospital on the southern side of Greenlane East (Figure 1, letter B) encountered a cavity. Initial borings had encountered only 2 cavities at 5-6 m depth, and the developers had not been concerned about these. Subcontractors had encountered some cavities at 0.5-1.5 m depth below the surface and had been drilling through them. They had been concerned with cost overruns and down time. When the large cavity was broken into, it was filled in before the Auckland City Council had time to react, because it would have cost too much to protect it (Lomas 2006). Fortunately Auckland geologist and caver, the late Les Kermode, heard about the discovery and, together with other speleologists, was given a brief window of opportunity to investigate it (Figures 3 & 6).

Subsequent archaeological investigations, documented in notes recently discovered amongst Les's files, show the existence of at least 5 lava caves (Figure 4). Comments written on the borehole logs included with Les's notes indicate that preliminary site investigations for Ascot Hospital narrowly missed all indications of lava caves or cavities in the area.

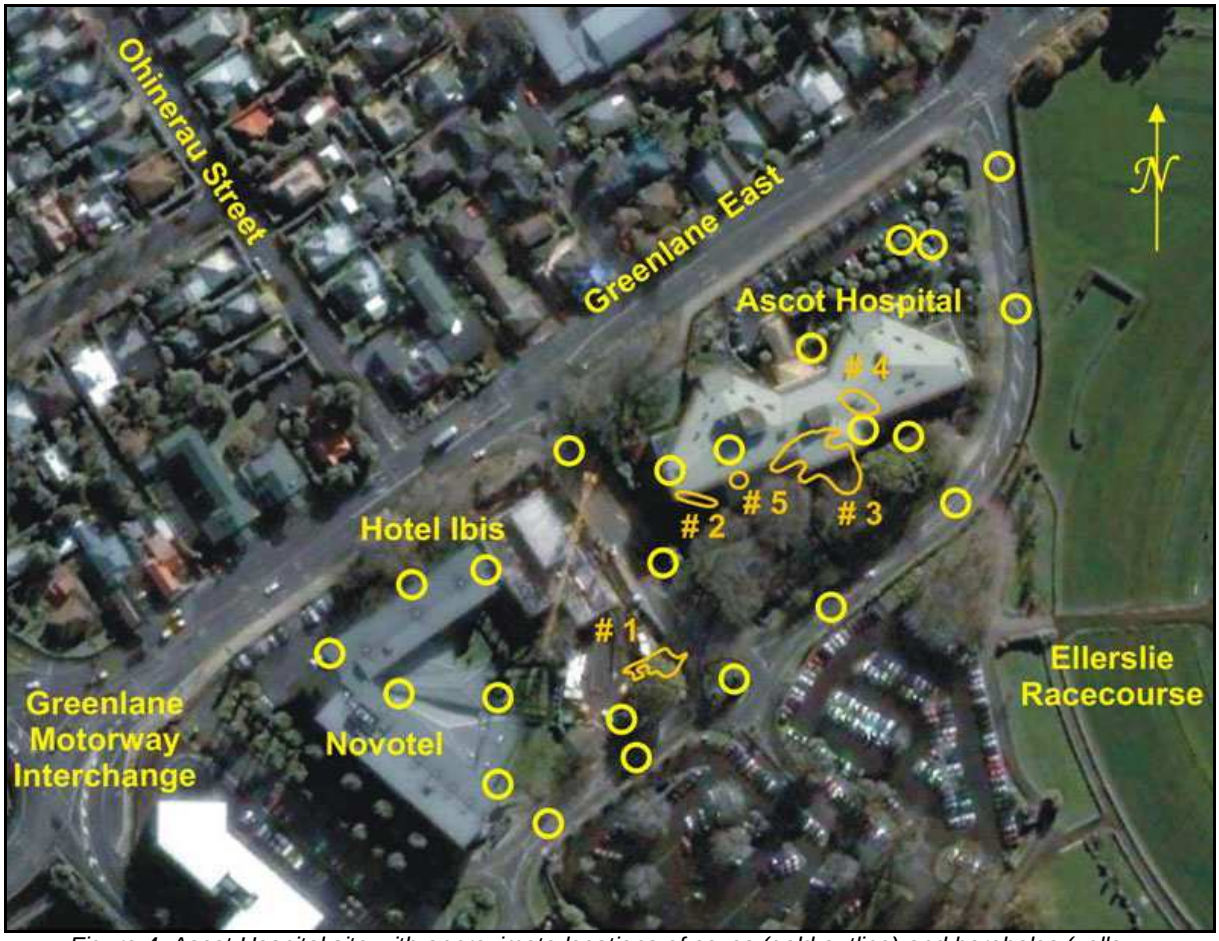


Figure 4. Ascot Hospital site with approximate locations of caves (gold outline) and boreholes (yellow circles). Cave #1 was 10 x 3 x 1 m tube, 0.5-1.5 m below lava surface. Cave #2 was ?17 x 3 x 1 m tube. Cave #3 was 20 x 20 x 1.5 m multi-chambered. Cave #4 was 13 x 6 x 1 m chamber with another smaller one 1.5 m below. Cave #5 was small rock-filled cavity.

The caves and cavities were then destroyed. This disappointing series of events is in stark contrast to the recent discovery of Kitenui Cave in Mt Albert (Lomas 2006), where gas pipe repairers accidentally broke into an unknown lava cave. They immediately sealed it off and informed the authorities. It has been mapped and studied and, according to well-known Auckland caver Peter Crossley, subsequently quoted in Lomas (2006), it "is one of the best lava caves in Auckland for cleanliness, complexity and size".

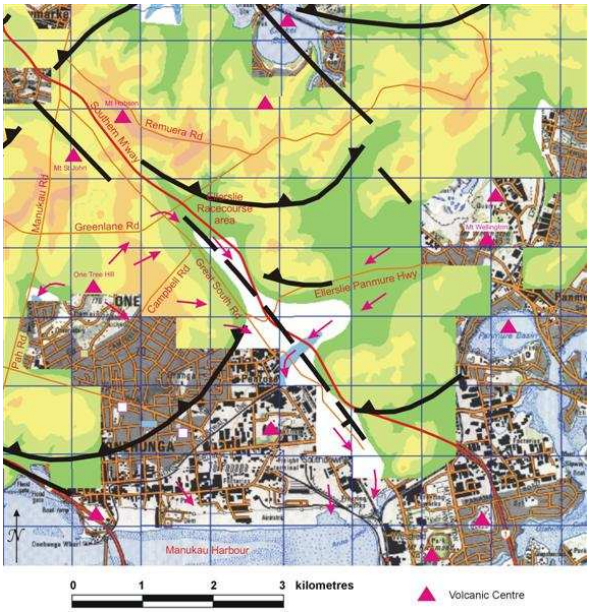


Figure 5. Part of the map from Kenny (2008) demonstrating the possible topography of Auckland before volcanic eruptions covered much of it in ash and lava (from 80+ m above present sea level in brown to 10 m below present sea level in blue). It shows a long valley, formed along a northwest-trending fault, running parallel to the Southern Motorway from near Mt Hobson to Otahuhu. Red arrows indicate postulated lava flow directions. Patches of untouched original map in Onehunga represent areas where depth to the top of the Waitemata Group sediments is unknown.

Meanwhile, back at Ellerslie, the Auckland City Council plan to rezone the area under the carpark alongside the Southern Motorway as Business 8 (Auckland City Council 2009a, 2009b, Clough 2004). This carpark rests on One Tree Hill lava flows (Figure 1, letter C). Let's hope that when this area is developed, more care is taken to ensure that if caves and cavities are encountered, they are better scrutinised than those destroyed under Ascot Hospital. The Auckland City Council district plan includes emergency procedures which can be invoked in just a few hours (Lomas 2006). If a cave is encountered, developers are obliged under section 5C.7.4A.3 of the district plan to open it for inspection by Council officers, produce plans and cross-sections, and record any notable features. Council officers, with expert assistance, then assess the value of the cave and are empowered to order its preservation or demolition.

And why have these lava caves formed so close to the end of the lava flow? The lava has originated from One Tree Hill, and in this direction it has reached as far as Ascot Ave and the southwestern corner of Ellerslie Racecourse (Figure 1). According to Kenny (2008), this position coincides with a valley in the underlying, pre-lava flow topography, running approximately parallel to the Southern Motorway and formed by erosion along a northwest-trending fault in the underlying rock (Figure 5). I suggest that the lava has flowed northwards from One Tree Hill and filled this valley. But it did not stop – it probably turned right and flowed southeastwards, down this valley towards Penrose. More lava from One Tree Hill seems to have flowed directly into the same valley further southeast (down gradient). Later, lava from Mt Wellington entered the same valley from the east and also turned sharply southeastwards (Kermode 1992) (Figure 5), following the same valley, to flow over the top of the distal One Tree Hill lava, out to the Manukau Harbour in the vicinity of Anns Creek, Southdown.

References:

Auckland City Council (2009a). Proposed Plan Change No. 167, Concept Plan E11-22, Business 8 Zone, Mitchelson Street. http://www.aucklandcity.govt.nz/Council/documents/district/updates/t167/PM167decision.pdf

Auckland City Council (2009b). It's My Backyard. Future planning framework version 1.0. Chapter 5, Area plans. http://www.itsmybackyard.co.nz/resources/Chapter%205%20-%20Area%20plans%20v1.0.pdf

Cheeseman, T.F. 1875: Proceedings Auckland Institute, Third Meeting, 16th August, 1875. In Transactions and Proceedings of the Royal Society of New Zealand, Volume 8, p. 427. http://rsnz.natlib.govt.nz/volume/rsnz_08/rsnz_08_00_003990.html

Clough, R. 2004: Appendix 9: Proposed Zoning Changes – Ellerslie Racecource: Assessment of Effects on Historic and Archaeological Values. Report prepared for Auckland Racing Club. http://www.aucklandcity.govt.nz/Council/documents/district/updates/t167/appendix9.pdf

Ellerslie Residents (2008a). Local resident believed to have found entrance to "lost" lava caves. http://www.savethesuburbs.co.nz/2008/12/

Glucina, J. 2009: Hunt for burial caves. East and Bays Courier. http://www.stuff.co.nz/auckland/local-news/east-bays-courier/2255053/Hunt-for-burial-caves

Kenny, J.A. 2008. Northland Allochthon-related slope failures within the Waitemata Group. Geocene 3, pp. 5-7.

Kermode, L.O. 1992: Geology of the Auckland urban area. 1:50 000. Institute of Geological and Nuclear Sciences geological map 2. 1 sheet + 63p. Lower Hutt, New Zealand.

Lomas, D. 2006: Cave New World. Heritage New Zealand Winter 2006. New Zealand Historic Places Trust Pouhere Taonga. http://www.historic.org.nz/magazinefeatures/2006Winter/2006_Winter_CaveNewWorld%20.htm

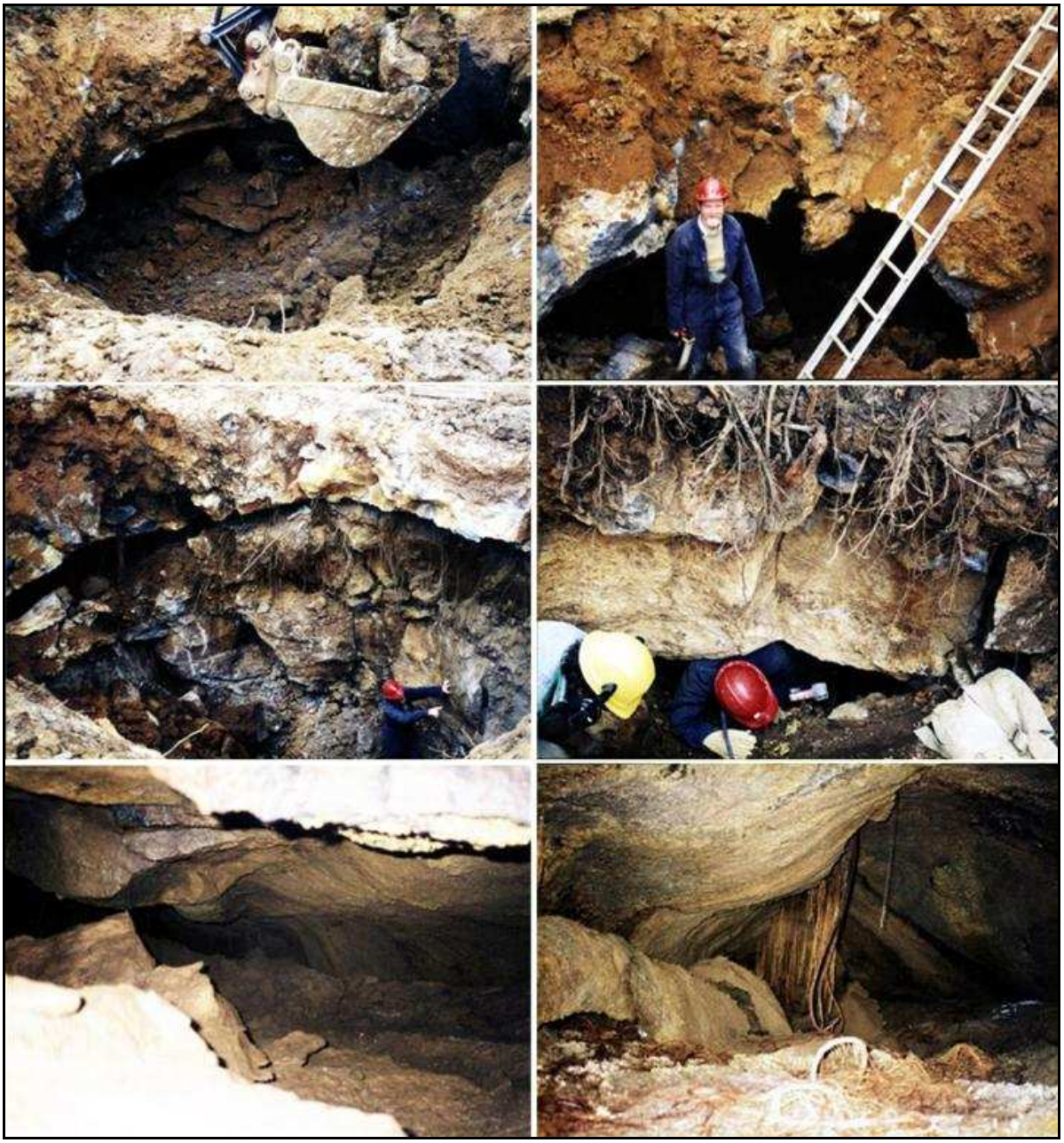


Figure 6. Photos taken in November 1997 and January 1998. Les Kermode is in the red hard-hat.

THE LOST JETTIES
Margaret Morley

Today the Pakuranga Highway conjures up visions of three stalled lanes of commuter traffic, but from 1915 to the 1950s, there was a quiet two-lane concrete road. Initially crossing the Tamaki Estuary was by a rickety punt, followed by the first Panmure bridge built in 1867. It was a toll bridge with a 12 m swing section manually opened to allow scows to pass through. Before that water access between the east and Auckland was paramount. The alternative was a long way round via Otahuhu.

Prior to the roads, transport was by smaller vessels which simply sat on the Tamaki Estuary mud between tides while carts were loaded or unloaded (Johnson 1988). Local farmers used both log and basalt jetties on the Tamaki Estuary to allow larger, shallow draught scows and cutters to take their produce to Auckland e.g. chaff, wheat, butter, vegetables, and bring back supplies. The bags were shot from drays onto the boats down wooden shutes. Once on board they were positioned by wheelbarrow.

Small quarry operators hewed basalt blocks from lava flows. Basalt from these quarries was transported by sea from nearby jetties for use in buildings and kerbstones in the city (Fig. 1). Remnants of several quarries and jetties are found along the Pakuranga Arm of the Tamaki Estuary (Alan La Roche pers. comm.).

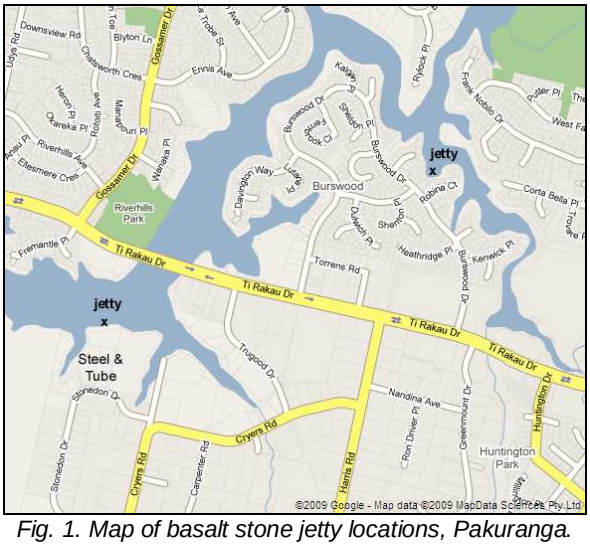


Fig. 1. Map of basalt stone jetty locations, Pakuranga.

One such quarry alongside a jetty is at the end of the walkway off Robina Place in Burswood Estate, Ti Rakau Drive (Figs. 2, 3). Access is a short scramble down through scrub. The jetty, about 10 m long by 4 m wide, is almost level with the water at high tide. Once down at water level, the quarry, cutting into the toe of a lava flow from Green Hill, becomes obvious behind the jetty.

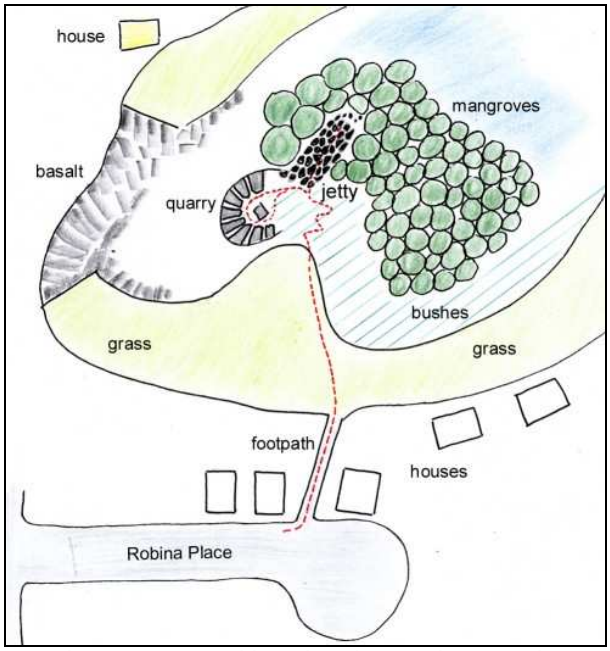


Fig. 2. Map of Robina Place jetty and surrounds.

On June 21 2009, GeoClub members walked the grass margins near the jetty and although some even took photographs of it from the opposite side of the bay, we did not recognise it enclosed among the mangroves. The exact position was explained to me by Alan La Roche. In the 19th century, mangroves were sparse in the upper reaches of the Tamaki, so at that time, the jetty would have had clear access to the channels. The water would also have been deeper, because since then sediment has built up due to runoff from urban development aided by the mangroves root systems.


Fig. 3. Photograph of Robina Place jetty and quarry, 2009.

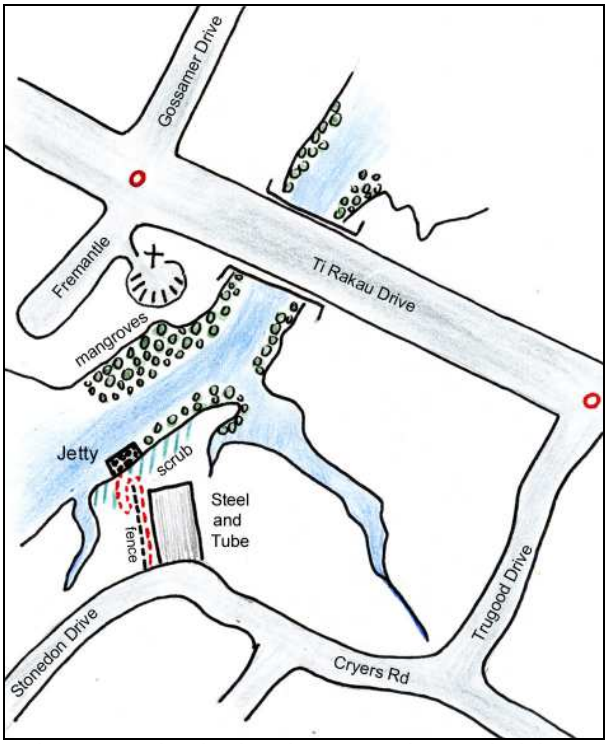


Fig. 4. Map showing location of Te Wharau Block jetty, Pakuranga.

A second, more substantial jetty and quarry, called Te Wharau Block, can be seen 400 m south-east of the modern Ti Rakau bridge over Pakuranga Creek (Figs. 1, 4). East Tamaki scows were brought alongside to load basalt blocks also quarried from an adjacent Green Hill lava flow, used for city kerbstones, CPO and Chelsea Sugar Works.

Unless you have a boat, access onto this jetty is through the Steel and Tube property on Stonedon Drive, off Trugood Drive, Pakuranga (Figs. 1, 4). You need to get permission. Enter by Gate A, and follow the left hand fence to the back boundary. Back track 10 m on the other side of the fence, then, push your way left through an overgrown track. The jetty itself is so disguised with bushes and weeds it is hard to see until you are on it. It is 7 m wide and one metre above high tide level, the seaward end drops down into the channel.

Adjacent to the jetty, forges were constructed for tempering stone chisels and picks (La Roche 1991). The site of these can be seen today as level platforms edged with lava blocks**.** Other levelled areas have been used for work shops near the jetty. A bank was cut through to allow an easy gradient down to the jetty. The toe of the lava flow visible in a 1975 photograph (La Roche 1991, p 224) has since been quarried away. A 6 m length of a very large tree still lying nearby was used for securing the scows during loading. The jetty today is very overgrown and guarded by mud, mangroves, crabs, gorse, Pacific oysters and Red Admiral butterflies! If getting there sounds like too much trouble, take your binoculars and view the jetty at low tide across the channel from the Baptist church in Fremantle Road (Figs. 1, 5).



Fig. 5. Photograph of Te Wharau Block jetty from Baptist Church, Fremantle Rd, 2009.

To our road-oriented minds we might have expected that basalt quarries nearer the city would have been used for kerb stones, but except for Meola Reef and Torpedo Bay, the Tamaki Estuary was the only basalt source linked by water directly to the foot of Queen Street. Land transport by horse and cart was very labour intensive, so water offered a better alternative.

As well as jetties, other photographs and information about places we have visited recently on GeoClub trips, e.g. Hampton Park, are in the book “The History of Howick and Pakuranga” (La Roche 1991).

Acknowledgements
Many thanks to historian Alan La Roche for describing the location of the Robina jetty and patiently answering many questions. Thanks also to Bruce Hayward for initiating the topic and formatting the article. Ashwaq Sabaa scanned my maps into digital format.

References

Johnson, David, 1988. Auckland by the Sea. David Bateman p.184.

La Roche, Alan, 1991. The History of Howick and Pakuranga. The Howick and District Historical Society p.302.

McLAUGHLIN'S VOLCANO (MATUKUTUREIA)
TUFF RING AND MOAT REMNANTS
Bruce Hayward

In May 2009 a GeoClub field trip visited McLaughlin's Mountain volcano and stonefields near Wiri in Manukau City. After many years of lobbying by archaeologists, the property was obtained by the Department of Conservation in 2008 for an historic reserve to protect the extensive pre-European stonefield gardens on the lava flows. Within the obtained reserve land are the remains of the extensively quarried scoria cone of McLaughlin's Mt.



Fig. 1. The swamp filling the remnant moat inside the tuff ring arc on the southwest side of McLaughlin's Mt, Manukau City, 2009.



Fig. 2. Photo from a commercial aeroplane taking off from Mangere Airport, 2008, showing small swamp wetland enclosed by tuff ring arc (circled) to the southwest of the quarried remnants of McLaughlin's Mt scoria cone (arrowed).

To the southwest of the scoria cone and unseen from public roads is a 100 m long x 10 m high arc remnant of the original tuff ring built up by the early phreatomagmatic eruptions at this centre. The scoria cone of McLaughlin's Mt grew in the centre of the maar explosion crater but did not completely fill the crater. Lava flows poured out, mainly from the base of the cone, overtopped the tuff ring and spread out as an apron around the southern, eastern and northern sides. To the southwest the lava flows only partly filled the moat between the base of the scoria cone and the tuff ring. There is still a 50-80 m wide gap between the toe of the flows and the inner slopes of the remaining tuff ring arc and this is now a seasonal wetland swamp – nearly dry in summer and water covered in winter. After the eruptions, this arcuate to oval-shaped depression probably filled with rainwater forming a freshwater lake. Over the succeeding thousands of years, sediment and peat has slowly accumulated in the lake and it has become a swamp.

In pre-European times the surrounding lava flow fields were extensively cultivated with associated stone walls, rows and heaps constructed. The scoria cone was terraced and acted as a defensive pa for the local iwi. At this time the depression may have been a small pond or swamp providing freshwater for the locals and their gardens.

Today two-thirds of the tuff ring remnant and enclosed wetland are in the DoC-owned reserve land and one-third is still in private ownership. Hopefully negotiations will succeed in preserving the remainder of this feature as an integral part of the pre-European landscape and maybe parts of the quarried cone that is on DoC land can be restored to its pre-European terraced form.

Jon Kay's Filksong Handbook Presents….

'THAT'S GEOLOGY'
Sung to the tune of Dean Martin's 'That's amore'

In the old quarry,
Where earth is king,
Rock meets tool,
Gee-oll-oh-jaay…..

When some quartz meets your eye,
And you can't pass it by,
That's geology!
(That's geology)

When rock hammers let fly,
With rock chips in your eye,
That's geology!
(That's geology)

When you're digging,
Down to find,
And down to find,
Sediment carbonaceous,
(Carbonaceous)

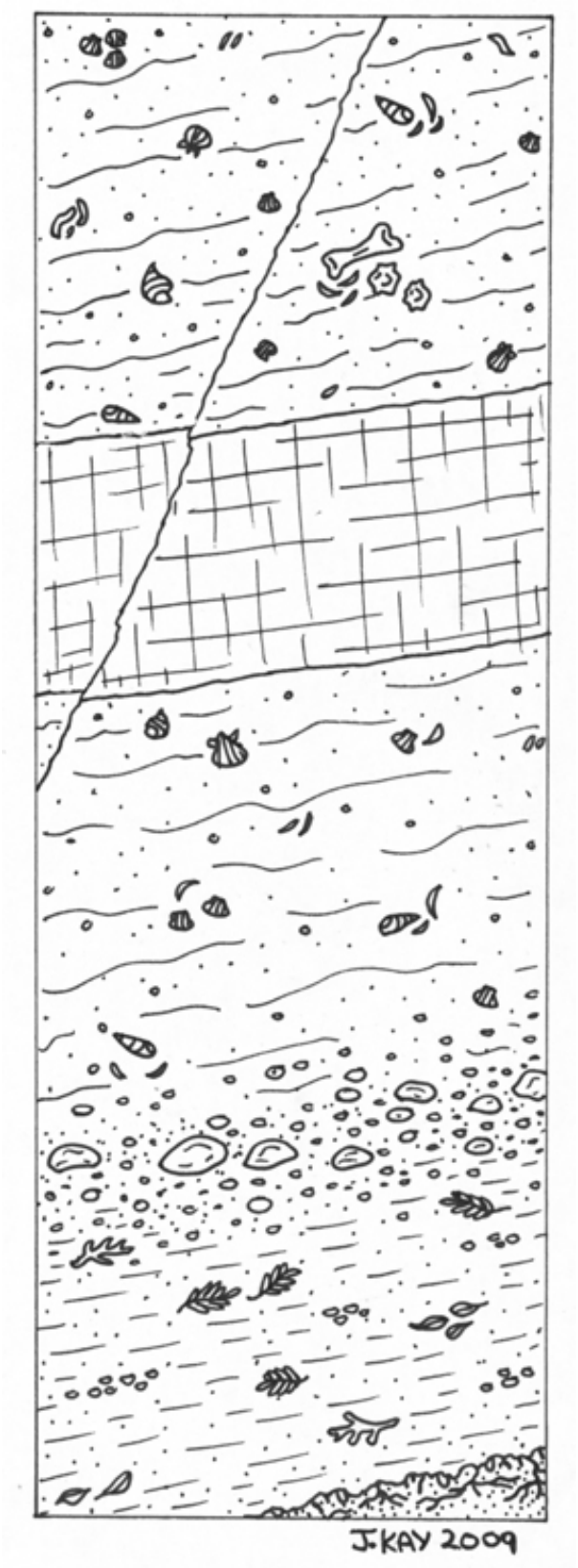
Filled with shells,
And bones and things,
And bones and things,
Dating from the cretaceous!
(The Cretaceous)

When you all start to drool,
At a rock-cutting tool,
That's geology!
(That's geology)

When your compass goes whack,
But you can't send it back….
That's hard luck,

When there's faults all about,
And your strata's in doubt…
Time for lunch!

Come with me,
Can't you see,
You can get a degree,
In geology!



'ICE AGE MEGA-FAUNA'
(Sung to the tune of 'Hotel California' by The Eagles)

On my 21st birthday,
Credit card in my hand,
With reckless abandon,
I had the event all planned,
Oh, the chance of a lifetime,
I sat up thinking all night,
My life was boring and my prospects dim,
Save for a temporal flight,

Walked in through the doorway,
I'd read their brochures well,
And as I clearly told myself,
It would be awesome and it would be swell,
I made a down payment,
and they whisked it away,
Strapped me in the time-machine,
And sent me on my way,

Voyagin' back,
To ice-age California,
Like you've never seen,
(Like you've never seen)
It's the Pleistocene,

Livin' the life,
With ice-age mega-fauna,
It's like a paradise,
(Like a paradise),
Except for all the ice,

AH! The Ice-age is freezing,
But where the pine forest ends,
There were lots of smiley-Smilodons,
None of them my friends,
Now they prowl in the darkness,
See-king my scent,
All deign to remember,
None deign to relent,



Crossed paths with a caveman,
Freed him from some vines,
He said, if there were some terror-birds here,
They'd be chewing on my spine,
Now he follows me all night n' day,
Took my pack in the middle of the night,
And watched my brochure play-ay,

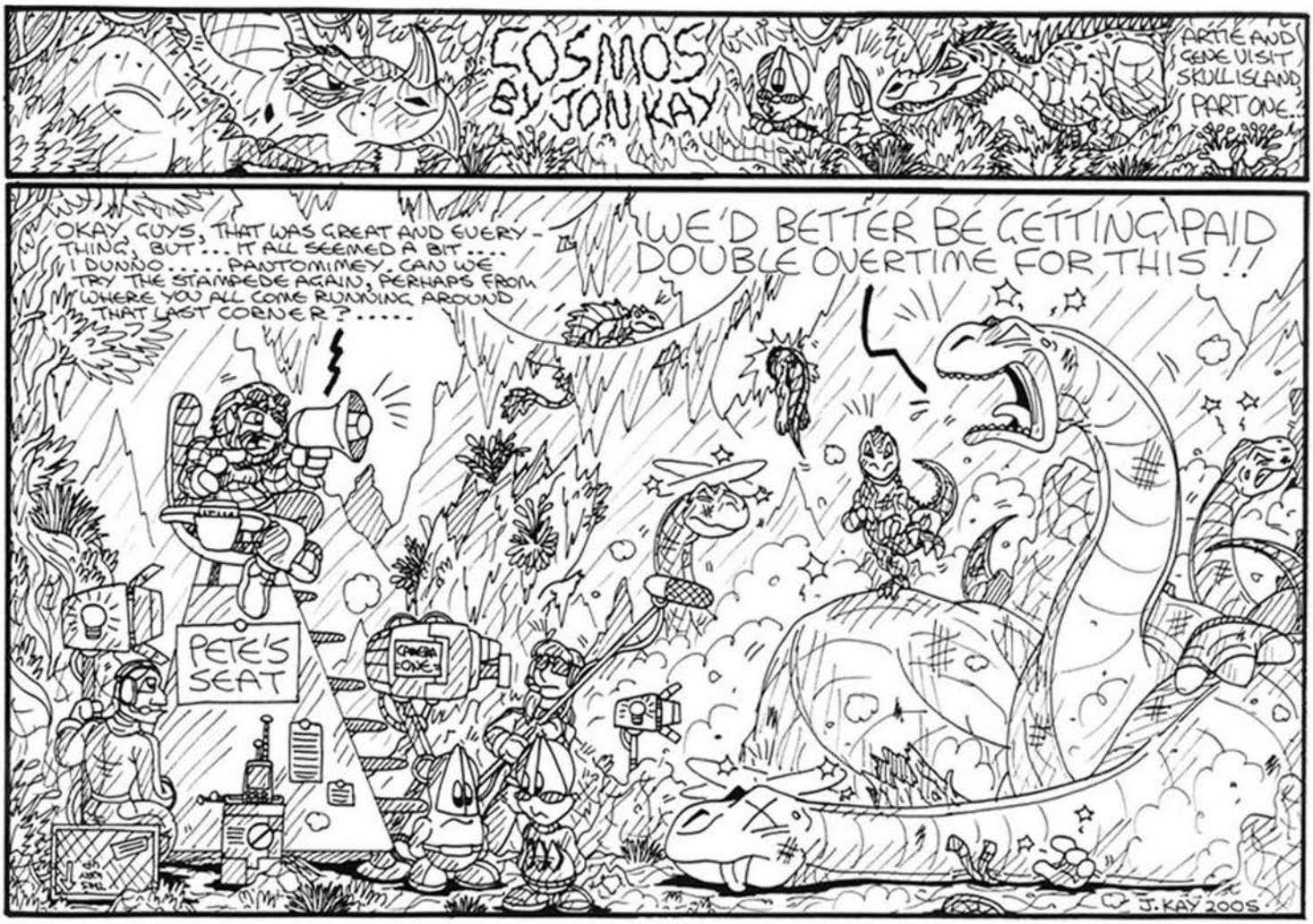
Voyagin' back,
To ice-age California,
Like you've never seen,
(Like you've never seen)
It's the Pleistocene,

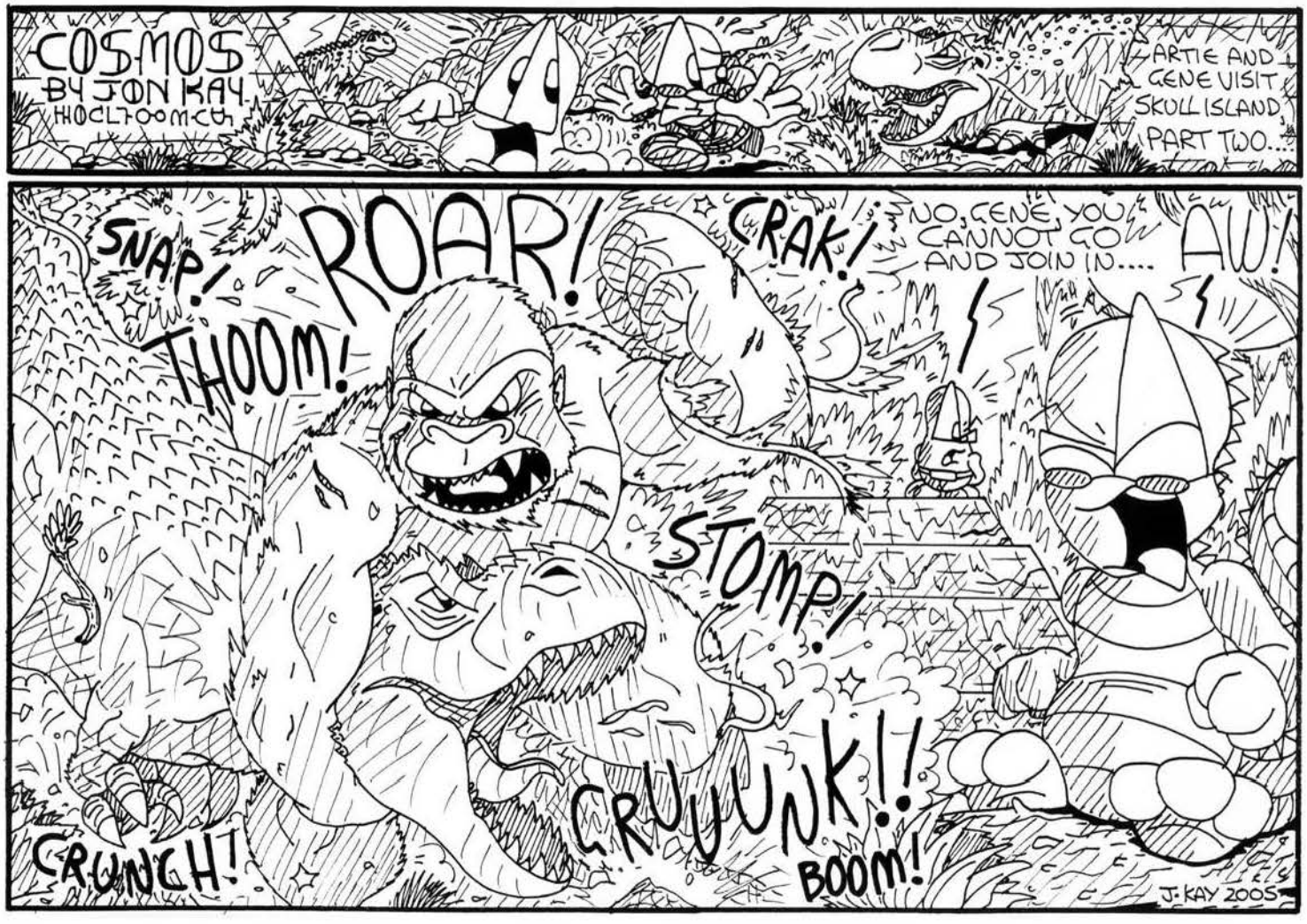
Livin' the life,
With ice-age mega-fauna,
It's like a paradise,
(Like a paradise)
Except for all the ice,

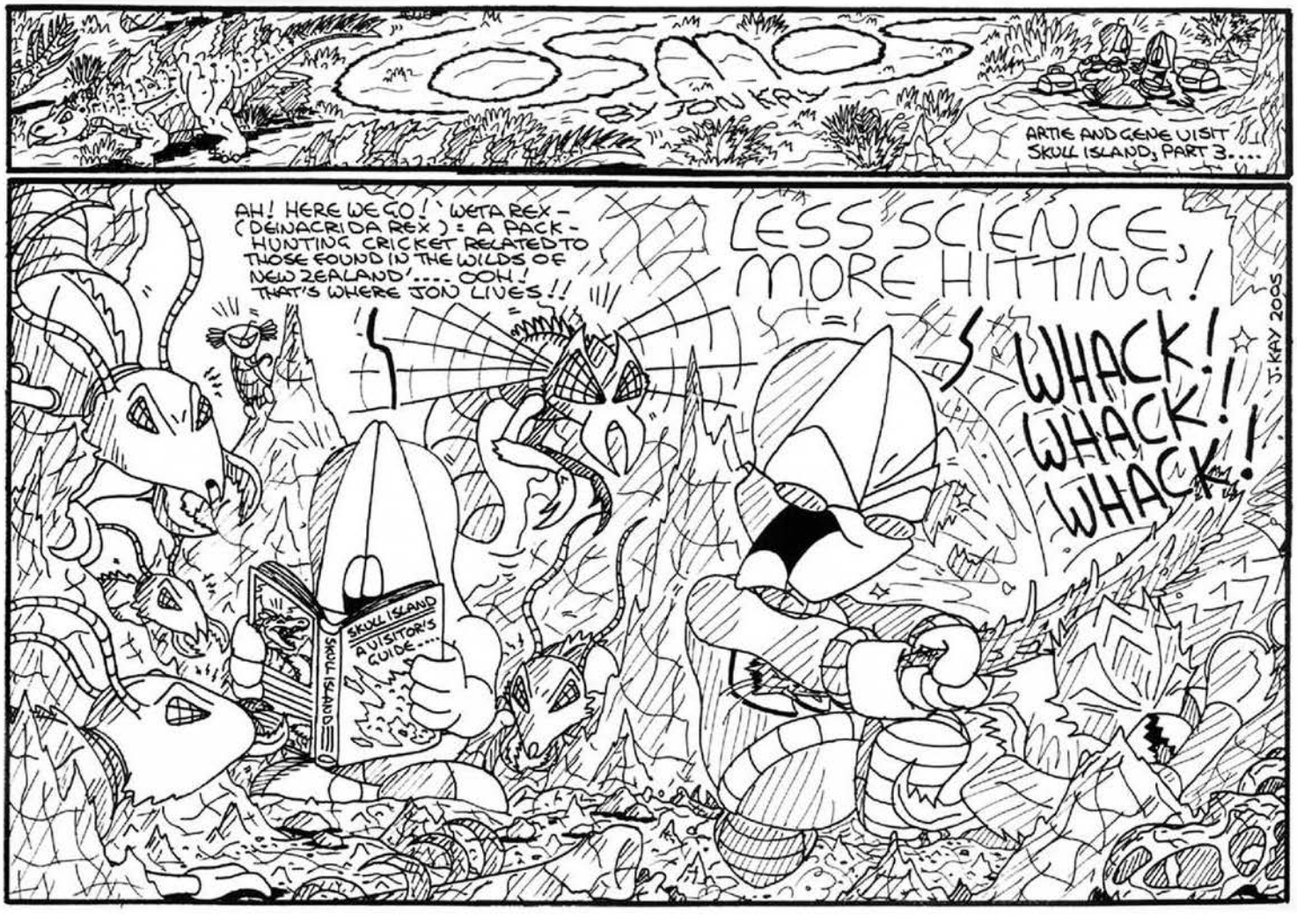
Mammoths on the tundra,
There's giant sloths and more,
Check out all the Mastodons,
And cave bears, by the score,
Cornered by the lions,
A horned elk-like beast,
The lions, with their massive jaws,
They will soon, have a feast,

Stuck here in the ice age,
It's really quite a bore,
But there ain't no way I'm gettin' back,
To the Age of man once more,
"Oh dear, said my time machine,
This message I've received,"
"Says right here, your cheque has bounced,
So I must….. sadly leave!"




COSMOS
BY JON KAY
ARTIE AND GENE VISIT SKULL ISLAND PART ONE...
OKAY GUYS, THAT WAS GREAT AND EVERY-THING, BUT... IT ALL SEEMED A BIT.... I DUNNO..... PANTOMIMEY, CAN WE TRY THE STAMPEDE AGAIN, PERHAPS FROM WHERE YOU ALL COME RUNNING AROUND THAT LAST CORNER?.....
WE'D BETTER BE GETTING PAID DOUBLE OVERTIME FOR THIS!!
PETE'S SEAT
J. KAY 2005

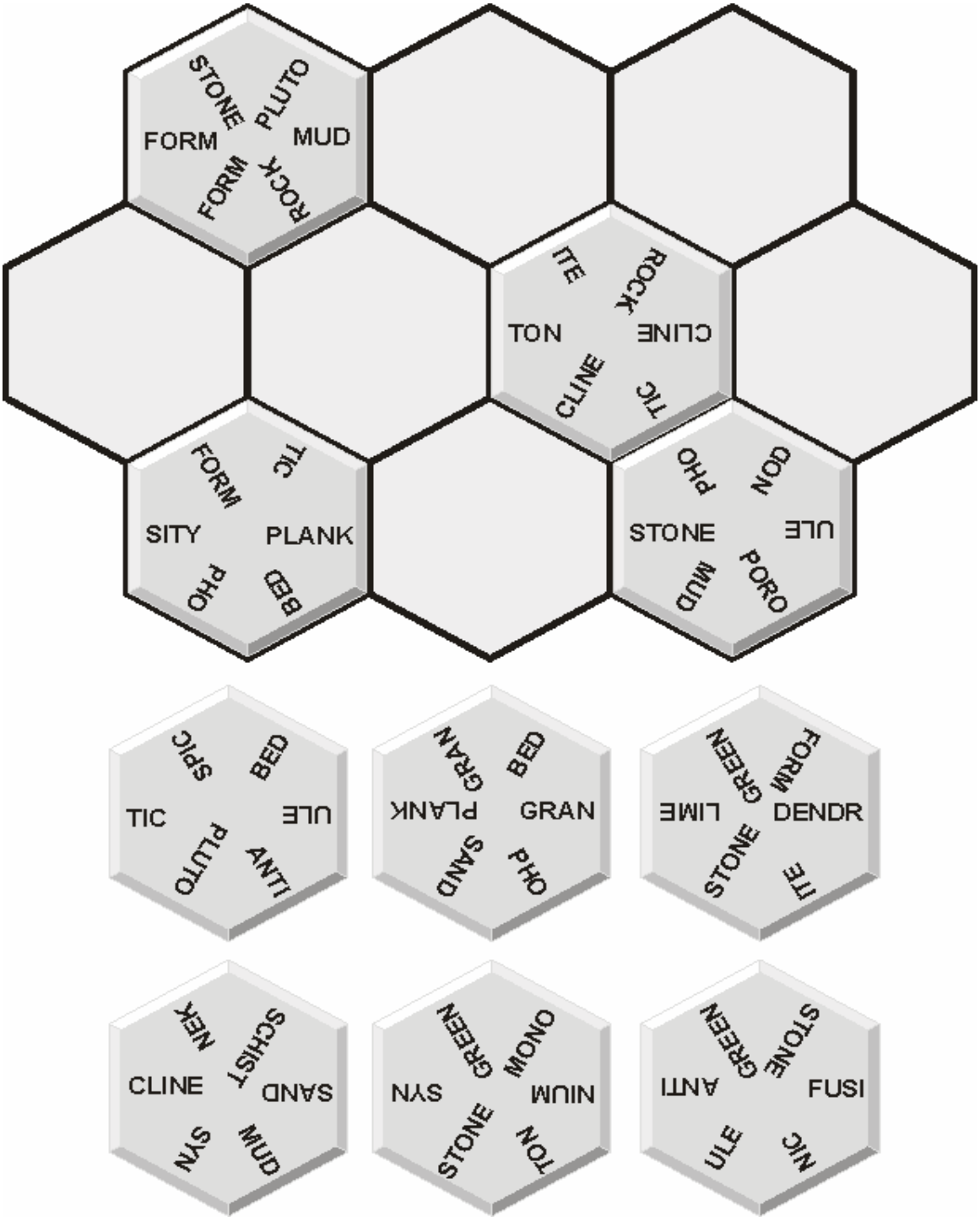

COSMOS
BY JON KAY
ARTIE AND GENE VISIT SKULL ISLAND PART TWO...
SNAP!
ROAR!
CRAK!
NO, GENE, YOU CANNOT GO AND JOIN IN....
AW!
THOOM!
STOMP!
CRUNCH!
GRUUUNK!!
BOOM!
J. KAY 2005


COSMOS
BY JON KAY
ARTIE AND GENE VISIT SKULL ISLAND, PART 3....
AH! HERE WE GO! 'WETA REX - (DEINACRIDA REX) = A PACK-HUNTING CRICKET RELATED TO THOSE FOUND IN THE WILDS OF NEW ZEALAND'.... OOH! THAT'S WHERE JON LIVES!!
SKULL ISLAND A VISITOR'S GUIDE....
LESS SCIENCE, MORE HITTING!
WHACK! WHACK! WHACK!
J. KAY 2005


COSMOS
BY JON KAY
ARTIE AND GENE VISIT SKULL ISLAND, PART 4....
AAAHHH.... A NICE BOAT RIDE THROUGH THE SWAMPS OF SKULL ISLAND.... COMPARED TO THE INSANITY OF THE JUNGLE, THIS IS DOWNRIGHT RELAXING!
UH OH.... THAT BETTER NOT BE THE 'JAWS' THEME MUSIC I'M HEARING RIGHT NOW.....
RAR!
J. KAY 2005

Word Puzzles

Geology Tantrix: Cut out the six hexagons at the bottom and place them on the pattern so all the geologic words make sense.



Word Puzzles

1 An important part; divide exactly into a given number
2 The result of light reflection and absorbtion
3 A shiver or small earthquake movement
4 A dome formed by upward movement of salts or lava
5 Chemical crust deposited by a mineral spring
6 A reddish metal, atomic number 29
7 To become visible, to seem or look in a particular way
8 A particular (named) bed within a group or formation
9 Line connecting points of equal atmospheric pressure
10 A quantity of magnitude but not direction
11 A trail of friction-induced light in the atmosphere
12 A hot spring that shoots hot water or steam into the air

1						R
2						R
3						R
4						R
5						R
6						R
7						R
8						R
9						R
10						R
11						R
12						R

Finish the words to find out what I found on the beach last week (highlighted boxes) .

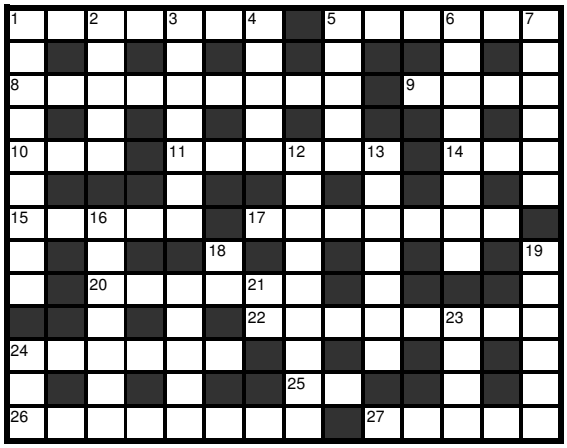
GeoWordOku
PLANKTICS: planktonic (drifting) foraminifera (single-celled organisms)

S I C A K	C P	T N
T N	A S L C K I T	P A
K P	N S	T N S I A

SUBLIMATE: to change from a solid to a gas (without going through liquid form)

I M E	E S	E T
T B A L	S U I T E	B I A S
L A	M B	S A U

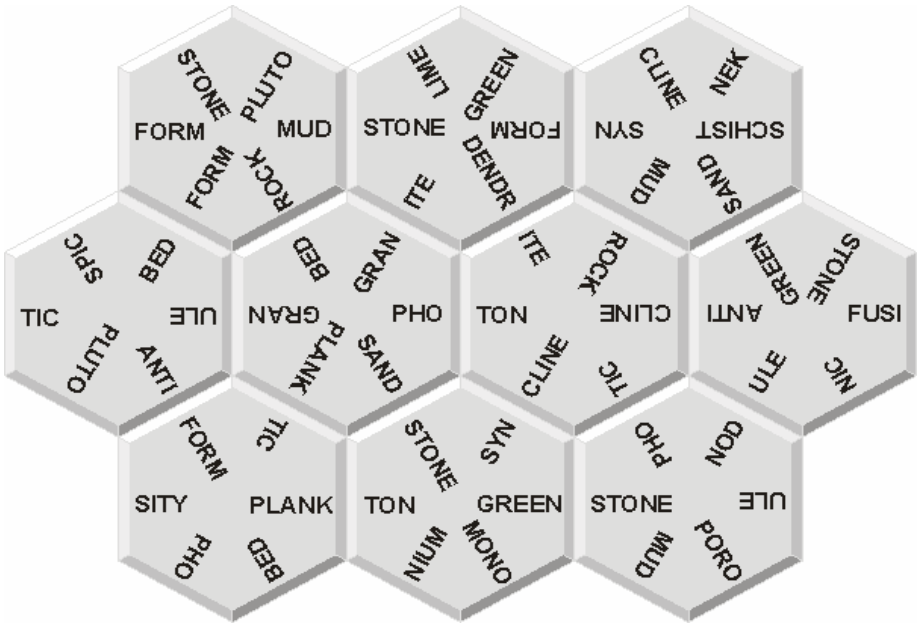
Crossword



Across
1 Very hard, like diamond *(7 letters)*
5 Stable interior portion of a continental plate *(6)*
8 Coarse-grained igneous rock with large phenocrysts *(9)*
9 Low pH, releases hydrogen ions *(4)*
10 Dihydrous oxide in solid state *(3)*
11 Rocks found in their place of deposition *(2, 5)*
14 Liquid formed underground by heating organic matter *(3)*
15 Yellow, red or brown coloured clay *(5)*
17 Sea lily or feather star from Echinodermata *(7)*
20 Weighed a lot under the influence of gravity *(6)*
22 The bottom surface of a fluvial channel *(8)*
24 Particles detached and transported away *(6)*
25 Symbol of yellow/green-fluorescing rare earth *(2)*
26 Solution containing hydroxide ions *(8)*
27 Uppermost part of a short valley or deep hollow *(5)*

Down
1 Double chain of linked silicate tetrahedra and cations *(9)*
2 Figure formed by two crystal faces with common line *(5)*
3 Calcium fluoride phosphate mineral, usually green *(7)*
4 A layer or bed becomes less thick *(5)*
5 The topmost point or line of a hill *(5)*
6 Structure produced by deformation or faulting *(8)*
7 A small, hard rounded lump of mineral/s *(6)*
12 To expose to or treat with radiation (*9)*
13 Something not given a noun to describe it *(7)*
16 A small mound or hill *(7)*
18 Symbol of a poisonous metalloid with several forms *(2)*
19 Sedimentary clastic rock with grain size exceeding 2mm *(6)*
21 Symbol of a soft, trivalent rare-earth metal stable in air *(2)*
23 A narrow raised ridge, shelf or bank of earth or sand *(4)*
24 Second order time segment of several hundred My *(3)*

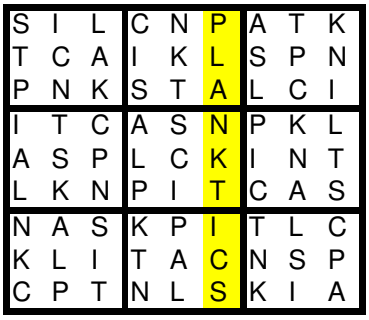
Word Puzzle Answers



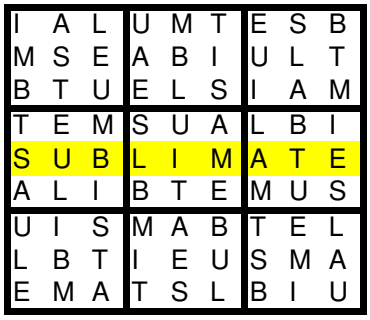
1	FACTOR	F	A	C	T	O	R
2	COLOUR	C	O	L	O	U	R
3	TREMOR	T	R	E	M	O	R
4	DIAPIR	D	I	A	P	I	R
5	SINTER	S	I	N	T	E	R
6	COPPER	C	O	P	P	E	R
7	APPEAR	A	P	P	E	A	R
8	MEMBER	M	E	M	B	E	R
9	ISOBAR	I	S	O	B	A	R
10	SCALAR	S	C	A	L	A	R
11	METEOR	M	E	T	E	O	R
12	GEYSER	G	E	Y	S	E	R

I found clean pebbles on the beach.

A	D	A	M	A	N	T		C	R	A	T	O	N
M		N		P		H		R			E		O
P	E	G	M	A	T	I	T	E		A	C	I	D
H		L		T		N		S			T		U
I	C	E		I	N	S	I	T	U		O	I	L
B				T			R		N		N		E
O	C	H	R	E		C	R	I	N	O	I	D	
L		U			A		A		A		C		R
E		M	A	S	S	E	D		M				U
		M		H		R	I	V	E	R	B	E	D
E	R	O	D	E	D		A		D		E		I
R		C		L			T	B			R		T
A	L	K	A	L	I	N	E		C	O	M	B	E



S	I	L	C	N	P	A	T	K
T	C	A	I	K	L	S	P	N
P	N	K	S	T	A	L	C	I
I	T	C	A	S	N	P	K	L
A	S	P	L	C	K	I	N	T
L	K	N	P	I	T	C	A	S
N	A	S	K	P	I	T	L	C
K	L	I	T	A	C	N	S	P
C	P	T	N	L	S	K	I	A



I	A	L	U	M	T	E	S	B
M	S	E	A	B	I	U	L	T
B	T	U	E	L	S	I	A	M
T	E	M	S	U	A	L	B	I
S	U	B	L	I	M	A	T	E
A	L	I	B	T	E	M	U	S
U	I	S	M	A	B	T	E	L
L	B	T	I	E	U	S	M	A
E	M	A	T	S	L	B	I	U