# AGSHV Mid to North Coast Safari.
# Field guide for geomorphological & geological structures at Crescent Head.

## Introduction

The sedimentary sequences at Crescent Head are thought to represent Carboniferous – Permian accretionary complex sediments deposited to the east of a prominent continental, 'Andean-type' volcanic arc.

The sedimentary sequence found at the northern end of Pebbly Beach is interpreted to be an overall fining up sequence, consisting of interbedded atypical bouma turbidite sequence with coarse-grained, massive ungraded sandstone beds with uncommon granule conglomerate lenses.

Bouma sequences present are mainly B, C & E divisions.

- B - planar laminations, coarse to medium
- C - Cross-laminated rippled sandstone
- E - Hemipelagic/pelagic mud, usually structureless.

The overall thickness of bedding located at Pebbly Beach (northern and southern end) of this sequence is 257 m. The average thickness of individual beds ranges between 1 m and 2.5 m for sandstone beds, between 4 cm and 30 cm for siltstone mudstone turbidites, between 0.5 cm and – 2 cm for mudstone, and between 1 cm and 5 cm for granule conglomerate lenses. It can be interpreted that this portion of the sequence was deposited beyond, but proximal, to the continental-shelf in a deep-marine environment.

The Crescent Head Beds are interpreted as proximal to shelf, deep-marine turbidite sequence, consisting of clastic-rich sandstone interbedded with siltstone, mudstone and granule conglomerate lenses.

Throughout the Crescent Head Bed sequence, the presence of rip up clasts indicates high energy events. Meanwhile, the presence of seismic deformation features, possibly caused by movement on a localised fault associated with the wider volcanic-arc setting present during the time of deposition in the latest Permian, fits in with the regional tectonic setting of the New England Orogen *(Figure 1)*.

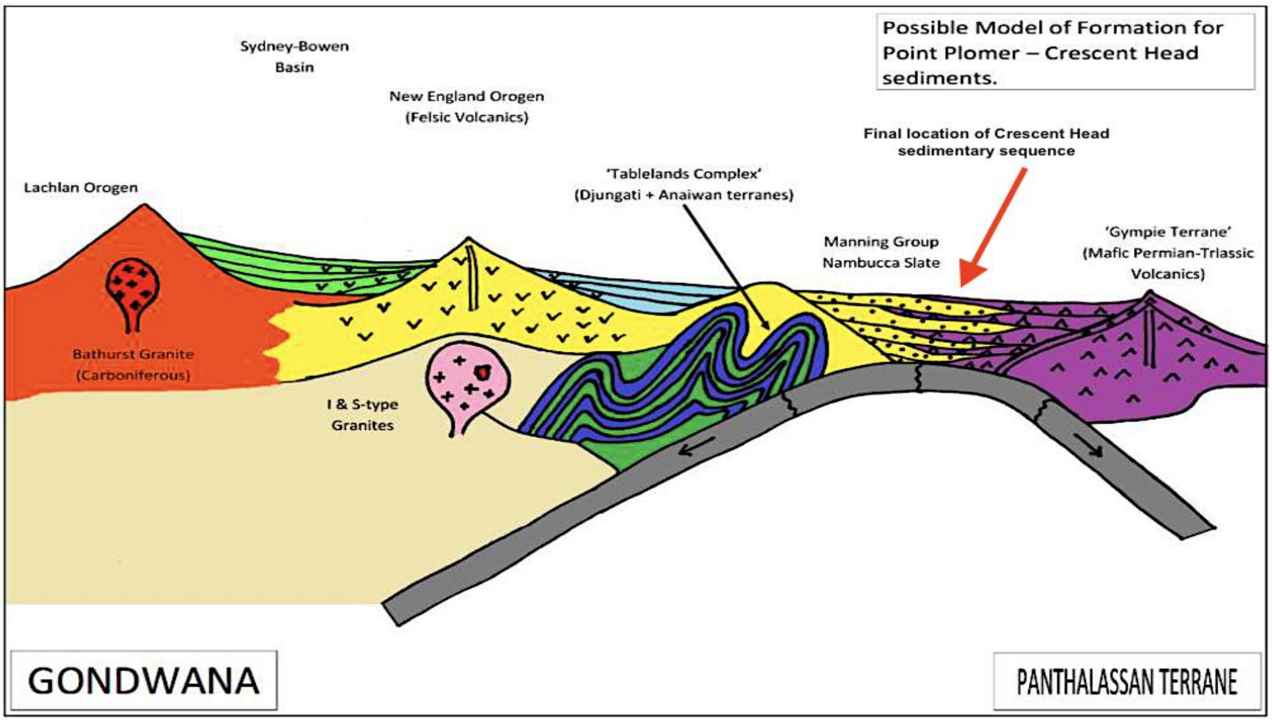



*Figure1: A schematic tectonic reconstruction of the final stages of deposition for the Crescent Head. Sedimentary sequences on the eastern margin of Gondwana in the latest Permian. (~ 254 Ma to 252 Ma).*

**Guide**. The following is a simplified identification guide for AGSHV members for identification of geomorphological and geological structures, that are located in channel deposits within a submarine fan sediment at the northern and southern ends of Pebbly Beach, Crescent Head.

**Bioturbation** can be observed in siltstone lenses located between bands of sandstone at Little Nobby, Crescent Head *(see photo below)*.

Sandstone beds at Little Nobby.

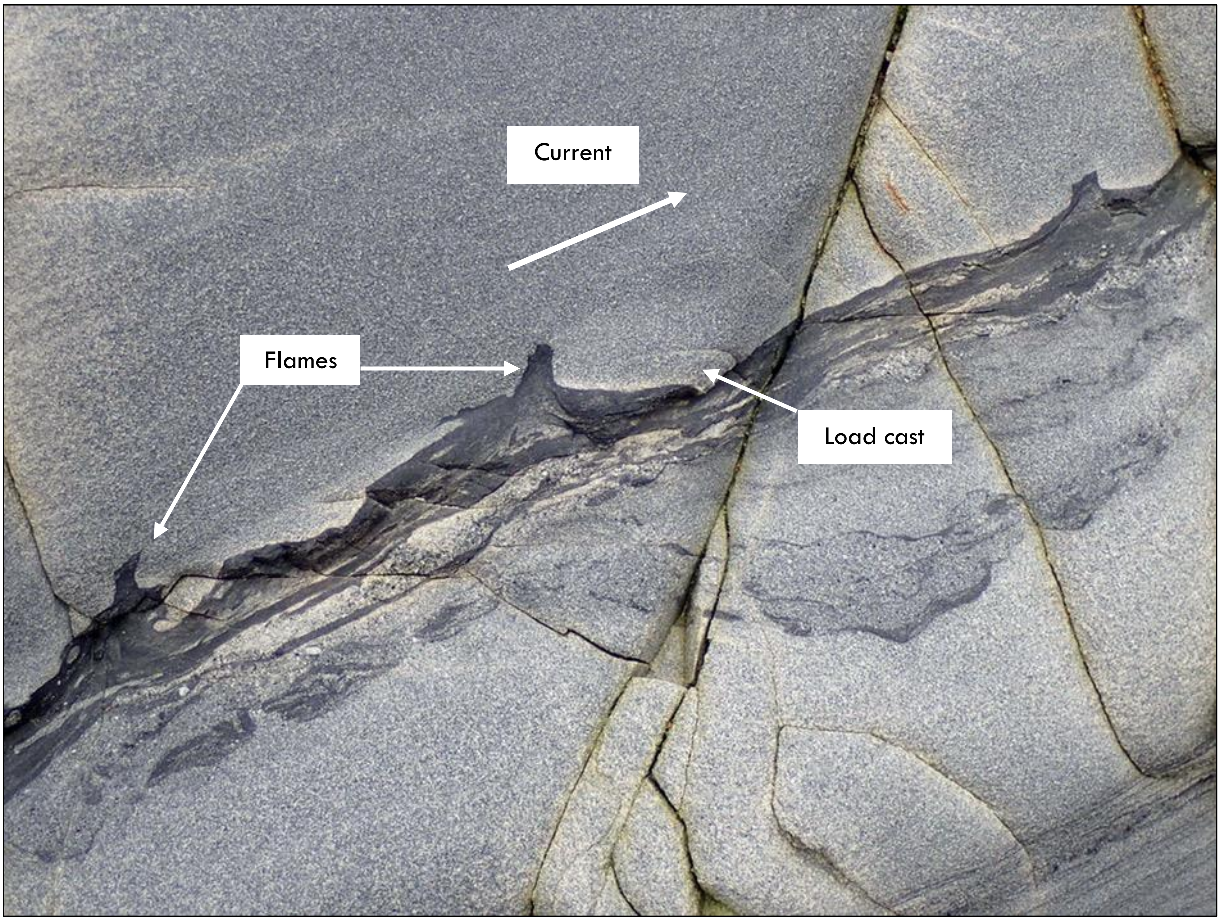
Note the narrow bands of dark siltstone between the sandstone beds - these show evidence of bioturbation.

Columns of reworked lighter- coloured sediment can be observed cutting through darker bands within the siltstone lenses. The most probable cause is through burrow construction and maintenance, as well as ingestion and defecation by invertebrates, probably worms.

**Flame structures** consist of sharp-crested wave or flame-shaped plumes of mud that have risen irregularly upward into an overlying layer (in this case) of sandstone *(see photo page 4)*.

The sand rapidly-deposited over the mud was denser than the unconsolidated mud below causing it to sink pushing the mud upwards into flames. The flames point in the direction of current flow.

**Load casts** are the features that formed alongside flame structures. They are the pendulous knobs of sand that descended downwards into the mud displacing it upwards to form the flames *(see photo page 4)*.




**Clastic or sand dykes.**

These are classified as injectite structures.

Clastic dykes form **rapidly** by fluidized injection of sedimentary material such as sand or **passively** by water, wind, and overpressure from gravity. The injected material fills an open fracture and cuts across sedimentary layers.

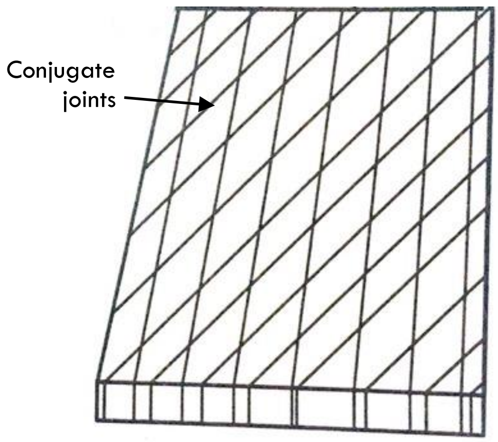
In the example below, two seams of fine sandstone have been injected upwards filling open fractures cutting across, mudstone/sandstone layers of sedimentary rock at Little Nobby.

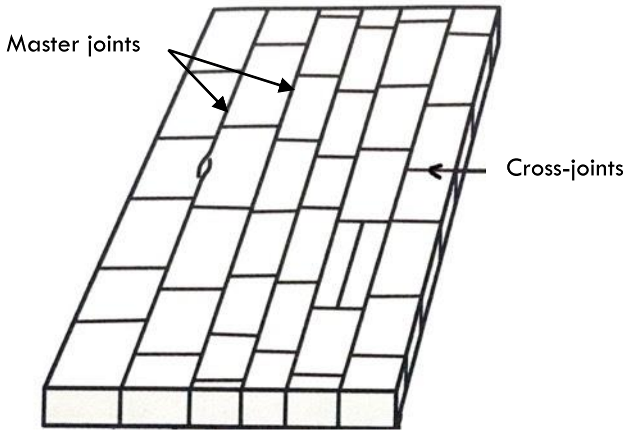
**Joints.** Fractures in rock in which movement has not occurred in a direction parallel to the plane of fracture.

Most commonly they form a wide-spread of parallel joints called a **joint set**.

**Conjugate Joint systems** are two intersecting sets with opposite shear sense intersecting between 30 to 60° commonly referred to as conjugate joints.

**Orthogonal joints** extend across intervals between systematic joints in sedimentary rocks at about 90°. They typically form a 'ladder-like' pattern when viewed on the bedding surface.




Mixture of Conjugate and Orthogonal joint sets sandstone on the rock platform at Little Nobby.

Orthogonal joint sets within sandstone on the rock platform at Little Nobby.

**Rip-up clasts** are formed when an erosive current flows over a bed of clay or mud, removes pieces and transports them some distance.

After deposition and deep burial by the accumulation of additional sediments, diagenesis transforms the clayey sediment rip up clasts into consolidated rock *(see photo below)*.

Rip-up clasts are often found at the base of sandy turbidites, in lag deposits at the base of channelized sandstone, and associated with subaqueous dunes and bars.

*Interbedded sandstone layer with poorly sorted rip-up clasts. Note how many of the rip-up clasts tilt to the right (imbrication) indicating current flow from left to right.*

**Weathering.**

This is the breakdown of rocks at the Earth's surface by the action of water, extremes of temperature, atmospheric gases and biological activity.

There are many types of weathering. However, at Crescent Head, **physical** (mechanical) and **chemical** weathering are the most obvious examples to be observed.

**Physical or mechanical** weathering are the processes that causes the disintegration of rocks without chemical change such as frost wedging, ice segregation, thermal stress, pressure release, salt wedging, and abrasion.

Spheroidal weathering, honeycomb weathering and abrasion are examples seen at Crescent Head.

**Chemical** weathering takes place when water, oxygen, carbon dioxide, and other chemical substances react with rock altering its composition.

**Spheroidal Weathering.** Jointing in the sandstone at Little Nobby produces blocks of rock.

The corner of a block of rock has a larger surface area to volume ratio than its core meaning processes such as salt wedging and abrasion by wind-blown sand and breaking waves weather and erode the corners more rapidly than the core producing a rounded top on the joint block.

This applies to sandstone blocks in situ and not to loose pieces of sandstone (cobbles and boulders) which have rounded by abrasion due to waves tumbling the rocks over each other.

Rounded sandstone blocks at Little Nobby do not show the normal characteristics of a spherically weathered rock because there are no concentric rings of rock surrounding the core which are usually the result of chemical weathering.

'Typical" spheroidal or onion-skin weathering that forms concentric layers of rock around a core.

*https://en.wikipedia.org/wiki/Spheroidal_weathering*

An example of spherical weathering on the rock platform adjacent to Little Nobby.

A few isolated rounded blocks of sandstone whose surface is undergoing honeycomb weathering.

Wave action has removed any loose pieces of rock and hydraulic plucking by waves have removed a piece of sandstone weakened from its core by jointing (arrow).

An unusual form of spherical weathering at the southern end of Pebbly Beach.

The jointing forming the sandstone blocks is obvious

These blocks of sandstone away from the direct action of waves most of the time. However, they are becoming rounded by processes of spherical weathering. Note that the tops are somewhat pointed.

**Honeycomb Weathering**. Regular adjoining cavities weathered into the surface of sandstone. They form by a combination of weathering processes:

a) Salt wedging: salt in seawater crystallises as it evaporates between grains on the surface of the sandstone loosening some grains.
b) Abrasion: wind and wave action remove the loose grains which may form a slight depression.
c) These two processes are repeated many times slowly deepening the hollow to from the typical honeycombed surface. As the hollows enlarge, the walls separating them eventually meet reducing the size of the sandstone block.

Honeycomb weathered sandstone, Little Nobby.

Note how the honeycomb weathered sandstone blocks are rounded. This is the result of spheroidal weathering processes.

Isolated pieces of sandstone on part of the rock platform regularly washed by waves are rounded.

Their surface is undergoing honeycomb weathering.

Note the chemical deposits of iron oxides in many of the joints.

Note that the iron oxide deposits within many of the joints are more resistant to the processes of physical weathering causing them to form raised ridges as the sandstone is being weathered away (tessellated pavement).

This is very obvious bottom centre.

Also note that the sandstone block shown by the **arrow** has almost completely weathered away as the overlapping 'honeycombs' have reduced the size of the sandstone block.

**En échelon veins** (or en échelon gash fractures) or **tension gashes** are structures within rock caused by noncoaxial shear. They are arranged diagonally with each vein stationed behind and to the right or behind and to the left of the unit ahead.

They appear as sets of short, parallel, planar, mineral-filled lenses (commonly quartz or calcite) within a body of a rock.

A large block of sandstone situated at the southern end of Crescent Head adjacent to folded strata containing many mineral-filled tension gashes. Note how those on the bottom right have rotated (sigmoidal tension gashes).

As soon as they form, they begin to rotate in the shear zone *(left diagram)*.

Subsequent growth of the fracture therefore causes the vein to take on a sigmoidal shape (*right diagram)*.

First, the rock gets sheared along some zone. Tension fractures open up oblique to that zone (as shown by the arrows here) and get filled in with mineral precipitations.

As shearing continues, these short mineral veins rotate with perhaps some folding. *https://mountainbeltway.wordpress.com/2010/08/24/tipping-your-tension-gash/amp/*

**Chatter mark** are small, curved fractures found on rock surfaces. Chatter marks are commonly 1–5 centimetres (½ – 2 inches) but may be sub-microscopic or as much as 50 cm in length. They occur mainly on hard, brittle rocks such as igneous rocks.

Chatter marks are formed from impact of boulders tumbled by wave action (in this case) or when transported along a river bed.

The above piece of sandstone contains crescent-shaped chatter marks.

Rocks containing such chatter marks can be found at the southern end of Pebbly Beach near the area of folded rocks.

**Folded Strata.**

Folding is the result of plastic deformation of rocks resulting from compression during collision and subduction along the eastern margin of the coast during the New England Orogen *(see Figure 1, page 2).*

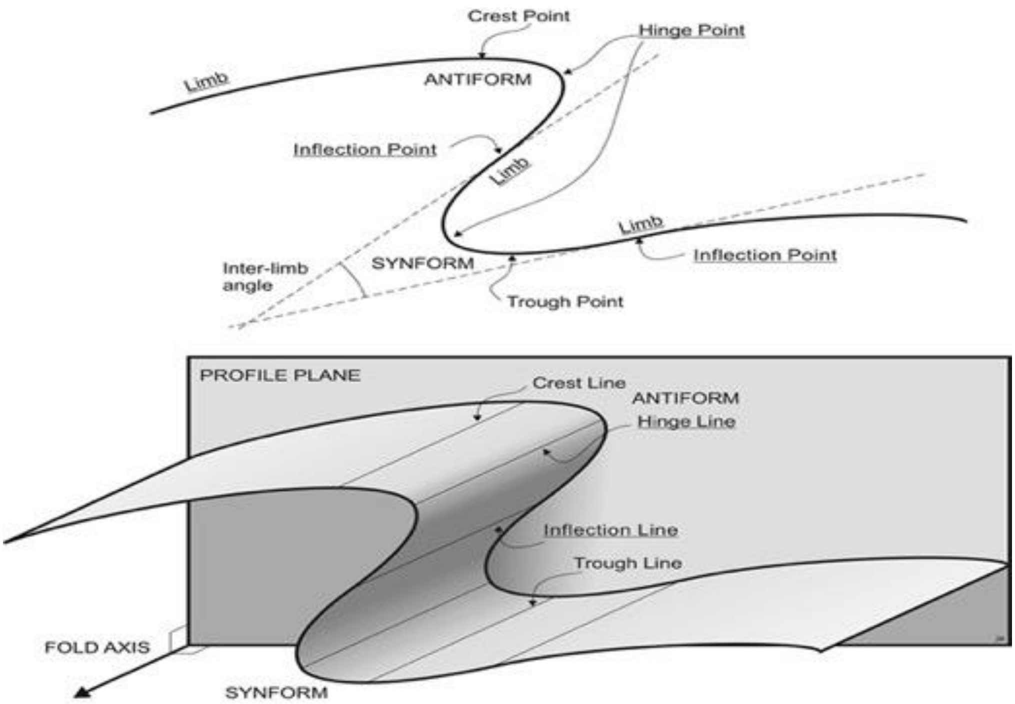
At the southern end of Pebbly Beach is an easily accessed outcrop of complexly folded strata situated below Crescent Head Golf Course.

Rocks exposed are independent of the sequence at the northern end of Pebbly Beach (Little Nobby) being a finer sequence of interbedded atypical bouma turbidite sequences with coarse-grained, massive ungraded sandstone beds with common granule conglomerate lenses.

A **recumbent fold** with associated **back thrust fault** and **wedge** can be observed.

Southern view of Crescent Head from Little Nobby and the folded strata
at the southern end of Pebbly Beach.

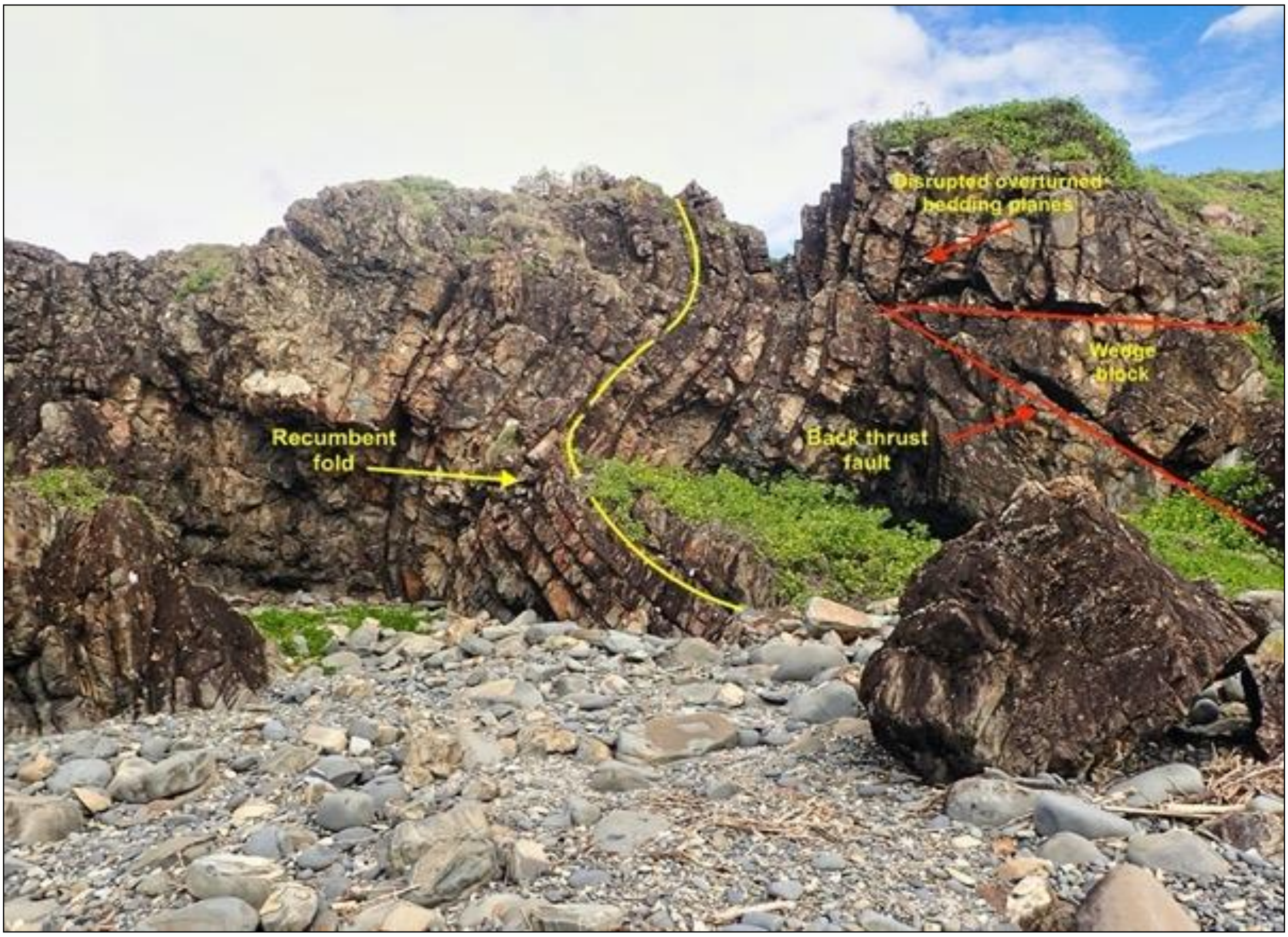
**Recumbent fold:** In an overturned fold, the beds dip in the same direction on both sides of the axial plane because one of those limbs being rotated through an angle of at least 90º. An extreme example of an overturned fold occurs when the axial plane is approaching horizontal – this is called a recumbent fold.



**Back thrusts:** In many cases back thrusts form as a result of parallel shortening in a late stage of thrust sequences. A back thrust would be directed in the opposite direction to development of a fold belt. Therefore, a back thrust is a thrust fault that dips in a direction opposite to that of thrust faults and fold structures.

Compressive forces forming recumbent fold with associated back thrust fault.

Outcrop of folded strata at the southern end of Pebbly Beach.
A recumbent fold with associated back thrust fault and wedge can be examined.
For the location of these structures, see photograph on the next page.



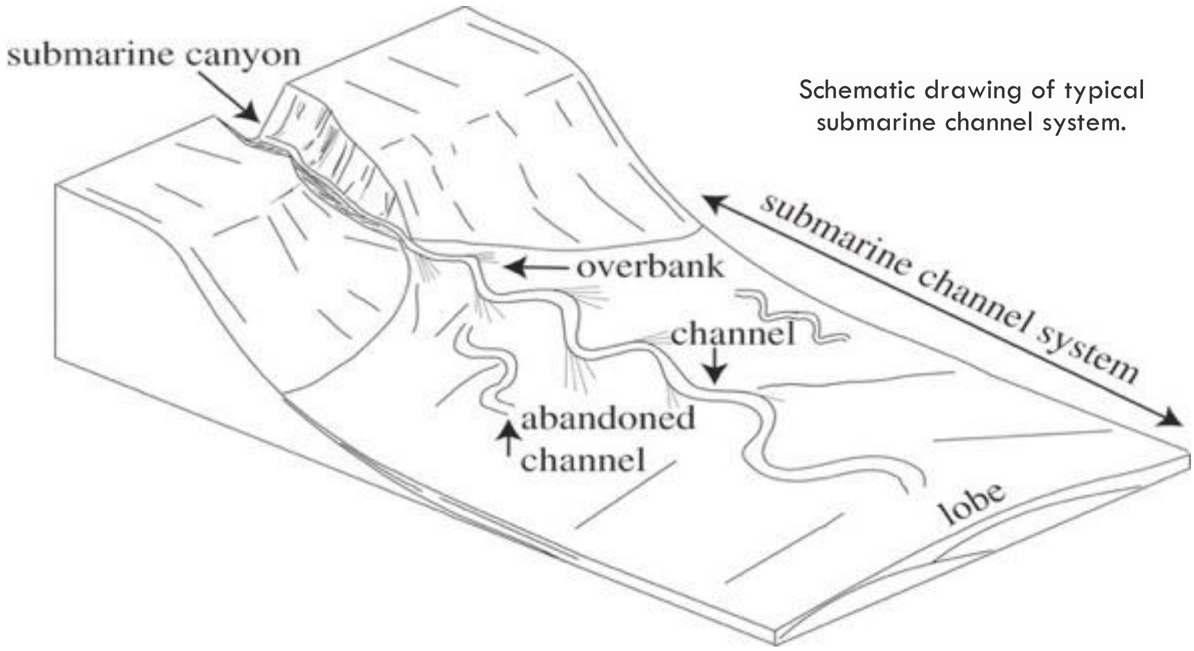

Location of a recumbent fold with associated back thrust fault and wedge.
Chatter marks can be found on some of the loose rocks.

## Some Further Information.

**Slump structures** are mainly found in sandy shales and mudstones, but may also be in sandstones. They are a result of the displacement and movement of unconsolidated sediments, and are found in areas with steep slopes and fast sedimentation rates. These structures often are subsequently faulted.

Slump structure. Note deformed stratified siltstone bedding and subsequent faulting.

**Submarine (neptunium) channels** are geomorphic features on submarine fans, linking net erosional elements like canyons and gullies to net depositional elements like submarine lobes *(see diagram below)*. They develop through both erosional and depositional processes, and have straight to highly sinuous planform geometries. Where they are flanked by aggregational levees or are entrenched into the seabed, they provide stable pathways through which sediment is transported and partitioned into different fan settings. Coarse-grained sediment commonly accumulates on the floors or at the mouths of submarine channels; finer-grained sediment preferentially accumulates on channel banks and on adjacent aggregational levees.




**Volcanoes and earthquakes** are often found in the same place, but are they related? Does one trigger the other? The answer seems to be yes – but not always. They are sometimes linked but are often independent events.

When a volcano erupts, the pressure of the rising magma forcing its way through the crust to the surface will often trigger earthquake activity. Scientists have been able to demonstrate this link and also know what type of earthquake to look for.

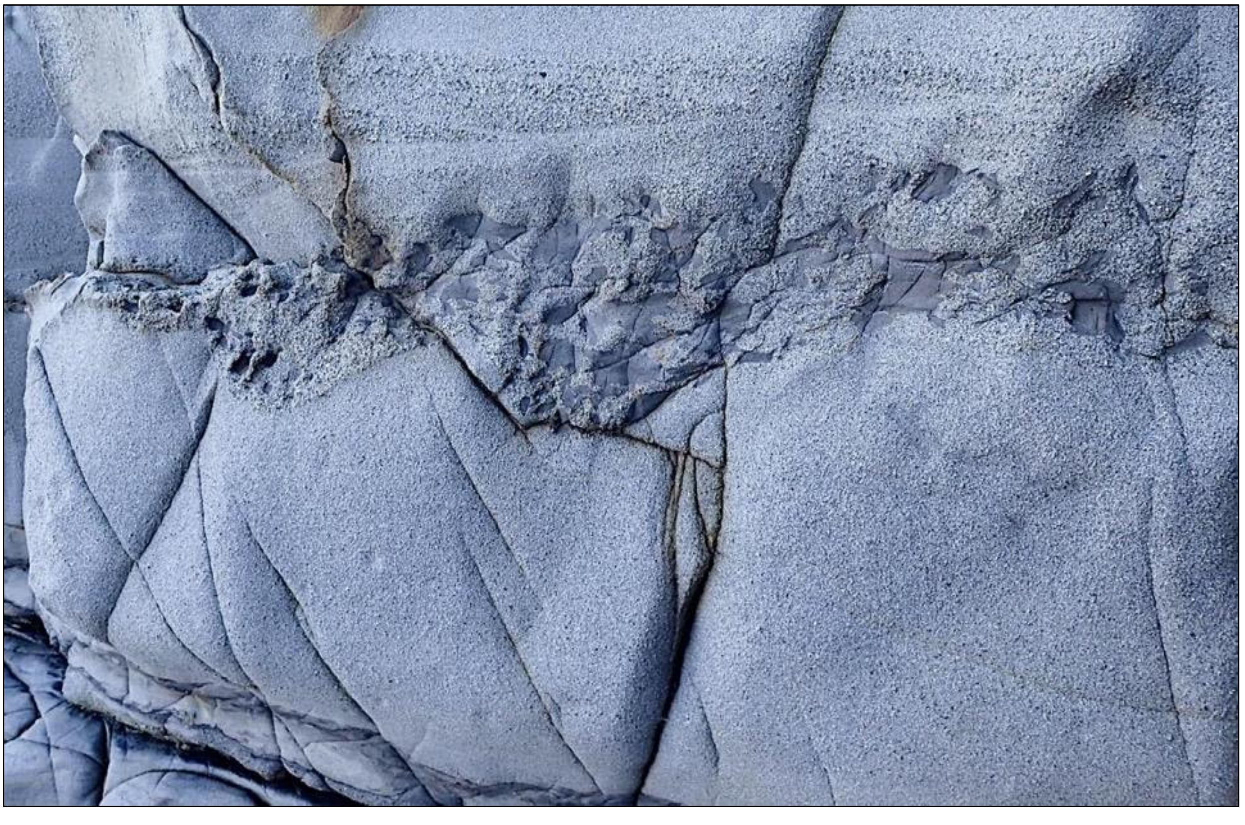
Conversely, an earthquake may trigger subsequent eruptions. As the crust changes and moves in a major earthquake, fissures or cracks can form that may act as pipelines for magma and future volcanoes. This is harder to monitor and test and is an area of active research.

**Injectite Structures** formed by sediment injection. Because they resemble intrusive and extrusive igneous features, much of the vocabulary for describing injectites, or clastic intrusions, comes from igneous geology. Sills are emplaced parallel to bedding, whereas dikes cut through bedding. The strata containing the intrusion are called host strata and the layers that feed the intrusion are the parent beds. Sand-injection features exhibit size scales from millimetres to kilometres, and have been seen in cores, borehole image logs, seismic sections, outcrops, aerial photographs and satellite images. Migration of fluids, including water and hydrocarbons from overpressure, gravity or seismic activity, can trigger the net migration of fluids into an unconsolidated sand-body. This overpressure can also provide the trigger mechanisms needed for sands to fluidize and inject. Clastic Injectites create additional fluid flow pathways, their impact depends on their timing and location.

**Some Other Structures**.

There are many interesting depositional structures to be seen at Little Nobby and Pebbly beach.

Some are shown in the following photographs - can you identify them?



This is a simplified identification guide for AGSHV members for the description and identification of geomorphological and geological structures at Crescent Head. All descriptions have been abridged and simplified. So, therefore I have not supplied references. For detailed information the reader can conduct more detailed research by searching the web regarding subject matter.

Compiled by Chris Morton and edited by Ron Evans. Photos by Chris Morton & Ron Evans.