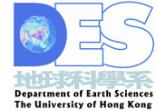


GEOLOGICAL FIELDTRIP TO MA SHI CHAU



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Introduction

Located in the middle of Tolo Harbour, Ma Shi Chau is a fascinating showcase of geological features. The island is rectangular in shape, with the long axis trending in a northeasterly direction. Most of the island is occupied by layered sedimentary rocks of shale, siltstone and sandstone. Volcanic sediments are present on the western and northwestern parts of the island. The rock layers in most exposures are dipping steeply and striking parallel to the direction of Tolo Channel.

The oldest sedimentary rocks in Ma Shi Chau were formed during the Permian about 270 million years ago in a shallow sea located on the edge of a continent. The climate was warm, and life was abundant. Many slump folds could be observed in the sedimentary rocks at Ma Shi Chau, suggesting the presence of active tectonic and earthquake activities during the time of deposition. During the Jurassic period, about 160 million years before present, extensive volcanic eruptions occurred in the area. Large amount of rock fragments, volcanic debris and lava fragments cumulated around volcanic centers. Magmas intruded into the underlying crust, gradually cooled and solidified to form granitic rocks. This crustal movement was caused by the northward subduction of a plate beneath South China. The plate convergence produced many faults and folded structures in the Permian rock in Ma Shi Chau.

Geological Structures

Many of the folds on Ma Shi Chau are soft-sediment deformations which were driven mainly by gravity. On this field trip, emphasis is placed on the following aspects:

- (1) Visualization of three dimensional geometry of the faults and folds;
- (2) Description and interpretation of the faults and folds and related structures in Ma Shi Chau; and
- (3) The relation between faults and folds and tectonic stress and plate motions.



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Key words:

granodiorite
lithic tuff
crystal tuff
rhyolite
volcaniclastic rock
flow banding
contact
max principal stress
min principal stress

dip-slip fault
strike-slip fault
displacement
strike and dip
brittle deformation
ductile deformation
en echelon gashes
crenulation
cleavage

buckle fold
kink fold
kink bands
isoclinal folds
riedels
S-C fabrics
axial plane
interlimb angle
soft-sediment deformation

slump fold
transposition
fold hinge
drag fold
plunging fold
syndimentary boudin
boudinage
concretion

Stops Description

Stop 1. Crystal tuff

The rock is massive, gray-colored and contains mineral and rock fragments ranging in size from a few mm to several cm. The matrix of the rock consists of quartz (grayish glass-like fragments), feldspar (whitish and pinkish grains), biotite mica (black, layered minerals) and occasionally hornblende (black slender crystals). These are minerals typically of an acid-intermediate igneous rock. The mineral grains and rock fragments are fragmentary, suggesting a depositional nature of the rock. The term 'volcaniclastic' is used to describe this particular type of rocks resulting from the deposition of volcanic debris. Tuff is the most common volcaniclastic rock composing of ash size particles.



Stop 2. Weathering

The weathering pattern, with the rock's outer layers displaying an intersecting network of cracks, is predominantly observed in boulders along the coast, in particular near the tidal zone. The cracking could have resulted from growth of salt crystals in joints, exerting a great pressure on the joint walls. Stress concentration at the tip of the cracks can cause the cracks to propagate through the rock.



Stop 3. Faulted layer with flow bands

At this stop, you can see a rhyolite layer with flow bands within a massive tuff. The contorting pattern of the flow bands suggests a viscous or slow-moving lava. The layer shows a 1-m offset along a fault.



Stop 4. Tuffaceous breccia and sandstone

In this outcrop, some layers contain large angular rock fragments several centimeters in diameter; such a rock is called a breccia, if the fragments are angular, or conglomerate, if they are round in shape. The angular nature of the fragments suggests that the fragments had not been transported for a long distance before they were deposited, since transportation by running water produces rounding of the pebbles. Some of the layers consisting of sand-sized grains are sandstones. The layer may represent a volcanic deposit formed during the initial stage of the volcanic eruption. The collapse of the rim of a crater lake might have triggered a landslide, causing a mass of rocks and debris to be deposited along the foothill of the crater.

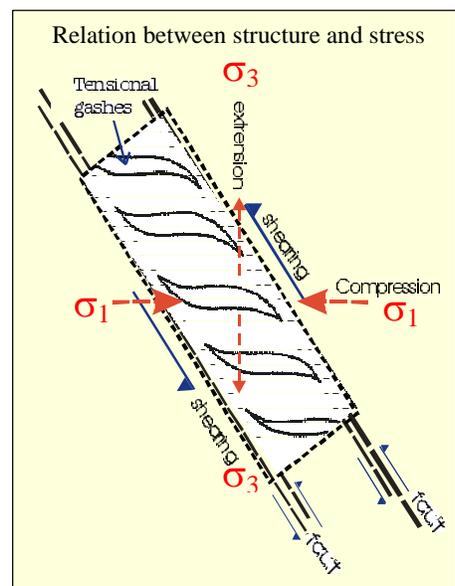


Stop 5. Contact between rock layers

At this stop, we can see two different rocks in contact with each other. The one further east is a breccia, same rock as the one at Stop 4. The one on the west is a greyish rock similar to the tuff seen at stop 1. This is a geological 'contact' between two layers. A careful examination shows that the tuff contains fragments of the reddish layer, suggesting that the tuff was deposited on top of the breccia. This kind of relation allows us to determine which layer is younger.

Stop 6. Quartz-filled fractured rocks

The sandstone contains several white-colored, lenticular-shaped bodies filled by quartz. The quartz lenses are fairly resistant to weathering and erosion. Occasionally in some of the openings you can find small quartz crystals with good crystal forms. The presence of these quartz-filled lenses shows how a rock can fracture when it is subjected to tectonic forces. As the two sides of a rock layer are sheared in opposite directions, the layer may fracture internally, causing lenticular-shaped openings to form. The openings were later filled by groundwater. The groundwater contained dissolved silica that precipitated quartz crystals when the physical conditions such as pressure and temperature changed in a manner such that the solubility of silica in the groundwater was reduced. The figure shows the relation between the orientation of the tension gashes and the principal stresses (Figure).



Stop 7. Sedimentary rocks with kink folds

With a careful examination, you can observe some small kink folds in the mudstone layers. These kink folds were formed by compression of thin layers. The layers were folded like a deck of playing cards. The hinges are sharp and well defined.

Stop 8. Boulder fragments

Many of these boulders are intensely fractured, with the fractures filled by secondary quartz crystals. A careful examination of the filling may find small well-formed crystals protruded from the fracture walls. Fracturing is a form of brittle deformation, indicating that the rocks were subjected to pressure after the rocks have become well consolidated. This is in contrast to the folding observed at many locations on the island, which are mostly soft-sediment deformation that occurred while the rock was still in a semi-consolidated state.



Stop 9. Synsedimentary Boudins

This is an interesting exposure showing how different rock types deform in different manners. The exposure contains a whitish finer-grained siltstone and some oval-shaped blocks of more resistant sandstone. The oval-shaped blocks are a feature known as boudins. They were once part of a single sandstone layer sandwiched between two softer siltstone beds. When the layers were compressed, the sandstone, being harder and more brittle, broke into a series of disconnected blocks, known as boudins. The softer siltstone layers behaved like a fluid and 'flowed', filling the openings between the boudins (Figure).



Stop 10. Fossil bearing rocks

The rock formation at Ma Shi Chau contains a variety of fossils such as crinoids, brachiopods, pteropods and corals. From these fossils, geologists have determined that the rock layers formed during the Permian period, about 270 million years before present. Occasionally the more careful visitor may find a fossil embedded in the rocks, such as the brachiopod in the picture. We implore all visitors to this island not to collect any fossils even when you find one in the rocks. Unfortunately some have done so.

Stop 11. Plunging fold

Try to follow a particular layer and observe how the layer changes direction at this exposure. It runs parallel to the coast on one side and turns toward the coast on the other side. This is an example of a fold structure. The point where the layer turns direction is the hinge of the fold. The hinge separating the folded layer into two limbs is called the hinge line. The hinge line of this particular fold is inclined at an angle to the horizon. We say that the hinge line is plunging and the fold is called a plunging fold. Try to visualize the three-dimensional geometry of the fold if you restore the layers to a horizontal direction.

Stop 12. Faulted rock layers

The three sandstone layers at this location form a good marker that allows us to determine the fault offset. We can see the layers terminate abruptly on a plane. About a meter seaward, the same set of layers reappears on the other side of the fault plane. The layers were clearly ruptured and displaced along the plane. A closer examination also shows that the layers are somewhat bent along the fault plane. The small folding associated with faulting is known as a drag fold. We can determine the direction of the fault motion from the marker beds as well as the shape of the drag fold.

Stop 13. Fault breccia

The rocks display an excellent example of a fault breccia. Angular fragments were torn off from the wall when the two sides of the fault ground against each other during the fault movement and were later cemented together.

Stop 14 Transposed sedimentary rock and slump folds

Along this coastal section we can find numerous examples of soft-sediment deformation and transposed layers. The softer layers deformed by plastic flow and the more competent ones are broken up into fragments and dispersed within the softer matrix. This process is called transposition. A remarkable slump fold is also present here. These slump folds were mainly driven by gravity, and probably triggered by an earthquake.

Stop 15. Folded quartz-sandstone and breccia

Folded quartz sandstones and breccias are exposed at this stop. The breccias, whitish and containing angular fragments up to 2 cm in size, are concentrated at the hinge area of the fold. The whitish sandstones contain cross-beddings, which are internal layers inclining at an oblique angle to the bedding.

