2.1 REGIONAL GEOLOGY

The tectonic evolution history of Borneo is complicated and had been hotly debated by different geologists such as C.S. Hutchison (2005), and Mazlan Madon (1999). It is basically created by a collision of a Luconia microcontinental block that came from the north into the West Borneo Basement which was part of Sundaland in the south.

Sarawak can be divided into four zones according to their geological history (Haile, 1974). The most northerly is the Miri Zone, dominated by shallow marine shelf sediments that were deposited upon older continental crust. The boundary between the Miri Zone and Sibu Zone is Tatau-Mersing Line (Hutchison, 1989) (Fig. 2.1).

The Sibu Zone is in the central part of Sarawak that is dominated by thick shale-sandstone turbidite sequences deposited upon oceanic crust. The rocks were uplifted in Late to Middle Eocene (William & Harahap, 1987; Hutchison, 2005) time. The boundary between the Sibu Zone and Kuching Zone is the Lupar Line (Tan, 1979).

The Kuching Zone located to the southwestern part of Sarawak consists of Jurassic – Cretaceous shelf deposits, molasses and related non-marine deposits on the edge of the West Borneo Basement Complex (Haile, 1974; Hutchison, 2005).

The most southerly zone is the West Borneo Basement (Haile, 1974) composed of Carboniferous – Permian basement rocks intruded by Cretaceous volcanic and plutonic rocks (William et al., 1988).

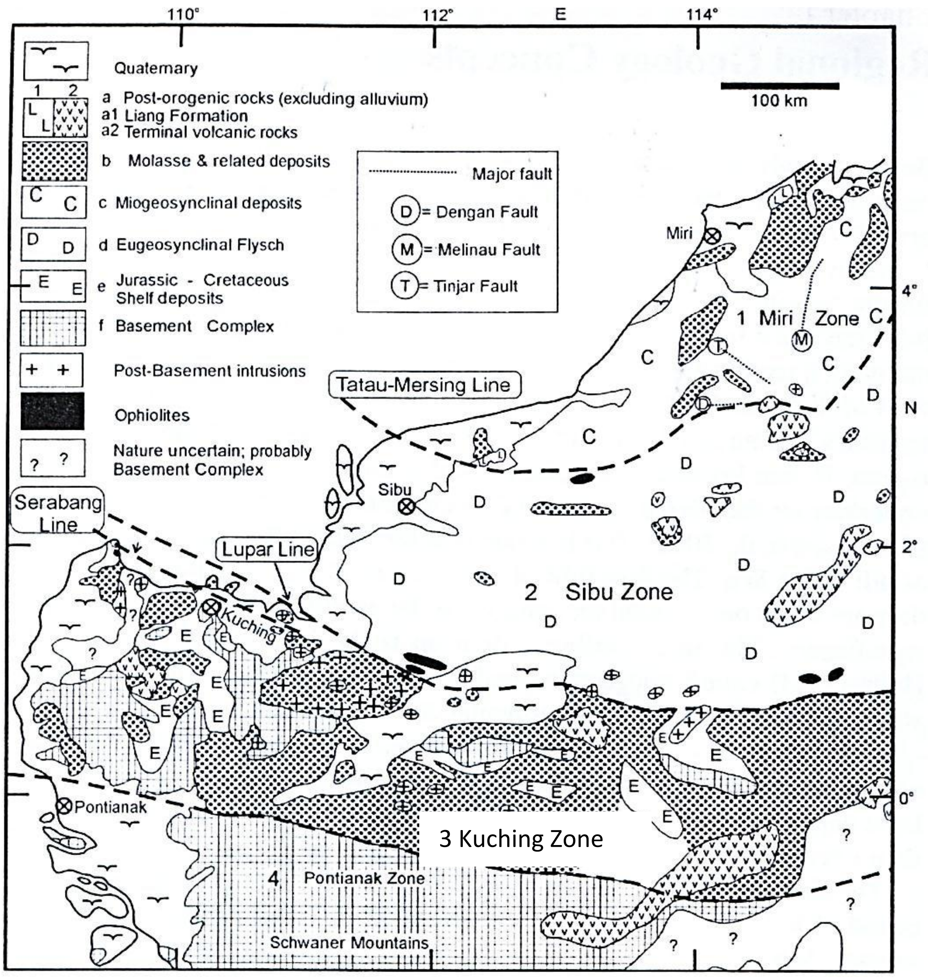

Fig. 2.1 Structural zones of northwest Borneo (after Hutchison, 2005).

In the Sibu Zone, the oldest formation at the base of the Rajang Group is the deep marine turbidites of the Balaga Formation that began to be deposited during the Late Cretaceous and ended in the Eocene by the Sarawak Orogeny (Leichti et al., 1960; Wolfenden, 1965; Hutchison, 1986; Mazlan, 1999; Kamaluddin Hassan, 2004; Hutchison, 2005). The Belaga Formation is highly deformed with steeply dipping low-grade metamorphic rocks as a result of being compressed, uplifted and sheared when Sundaland and the Luconia blocks collided (Fig. 2.2). This collision led to the subduction of the Rajang Sea beneath the South Borneo Block that uplifted the Belaga Formation were uplifted (Adam, 1965; Hutchison, 2005).

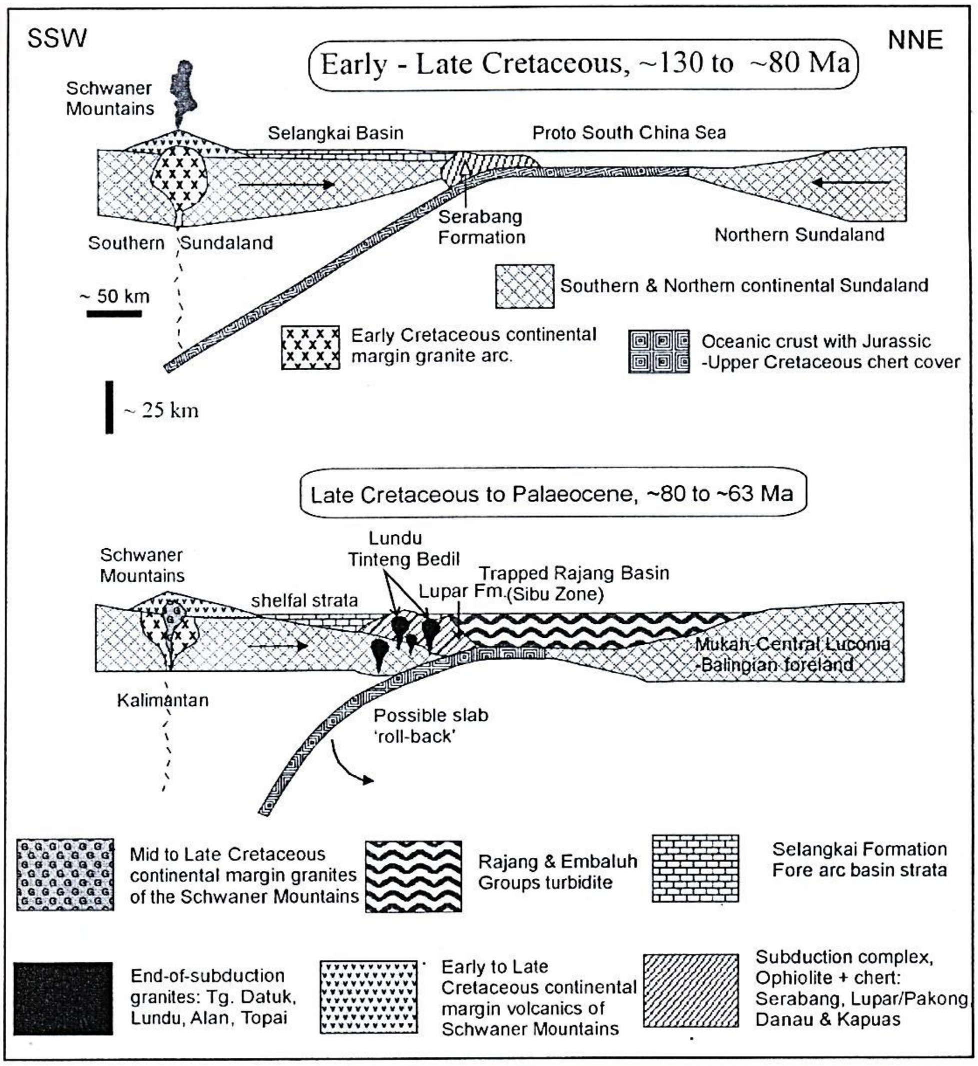

Fig. 2.2 NNE-SSW diagrammatic cross-section of the proposed plate-tectonic model for Early Cretaceous to Middle Eocene convergent tectonics in Sarawak. (After Moss, 1998; Hutchison, 2005).

The West Borneo Basement was the northern edge of Sundaland separated by the Rajang Sea from the Miri Zone which was the southern edge of the Luconia Microcontinent. The Luconia Block moved southwards to collide with the West Borneo Basement during Late Mesozoic to Early Cenozoic (James, 1984) time. The collision of the two continental blocks led to the uplifting of the deep sea sediments of the Sibu Zone to expose the deep sea turbiditic sequence of the Belaga Formation during Mesozoic to Early Cenozoic time. A drastic change from deep water Cretaceous turbidites to shallow marine and deltaic sediments of Oligocene-Miocene age took place as a result of the Late Eocene deformation and uplift caused by the Sarawak Orogeny (Adams, 1965; Hutchison, 2005).

The opening of the passive margin of the South China Sea in Eocene time redirected the stress to the adjacent MIri Zone Microcontinent and probably led to the extension of the Luconia Block in a WNW –SES direction. This extension might have caused the thinning of the crust and with an increase in sediment load derived from the uplifted Borneo continent that led to the sinking of the Luconia Block (Xia & Zhou, 1993; Dewey, 1982).

The clockwise rotation of Borneo that had been identified in the past by Schmidtke et al. (1990) and Fuller et al. (1999) might instead be caused by the oroclinal bending event as the microcontinents collided with each other. This oroclinal event was formed as a curved orogen and involved both the rotation and strike slip faulting along the Sibu Zone. The Rajang Sea closure was caused by the subsidence of the Miri Zone Microcontinent beneath the West Borneo Continent during the Late Eocene (James, 1984; Hazebrock & Tan, 1993; Hazebrock et al., 1994). The deep water sediments of the Rajang Sea were dominated by shale that tends to deform in a ductile way rather than in a brittle fashion. Vast quantities of marine shale were folded and faulted by sliding against each other in parallel or tangentially to the direction of the Rajang Sea closure.

The collision between these two continents during the Sarawak Orogeny might have occurred at different times in different places. The West Borneo Basement and Luconia Microcontinent collided at an angle and the compressional forces were distributed unevenly over the terranes leading to the closure of the Rajang Sea in different places that caused the hiatus of the sediments deposited. The oroclinal rotation of the plate was triggered by the collision due to the strong deformation of the argillaceous marine shale.

The uneven continental margin with differential distribution of the accreted argillaceous sediment contributed to ductile deformation rather than brittle deformation in which the continental margin tended to slide past each other as the compression forces increased. The rotation was in a clock-wise direction as can be deducted from the paleomagnetic studies of the Mesozoic and Cenozoic rocks (Fuller, et al., 1999). The paleomagnetization of Mesozoic Borneo was almost to the present west; while during Cenozoic time the magnetization shows almost present NNW. But most of the major faults lines such as Lupar Line, Tatau Mersing Line are aligned in a NW-SE direction extend offshore from the hinterland of Borneo (Ismail, 1999) suggesting they have been produced by oroclinal bending rather than rotation.

Overlying the Rajang Accretionary Prism sediments is a succession of Upper Eocene to Recent shallow water sediments in the Miri Zone. This is represented by the presence of richly fosilliferous shallow marine limestone bodies such as the Arip, Melinau, Subis and Sibuti that overlies the Belaga Formation.

2.2 GENERAL GEOLOGY OF TATAU AREA

The oldest sedimentary formation in the Tatau area is the deep marine turbiditic Belaga Formation of Eocene age. This basement rock had been thrusted up in compressional steeply dipping and complexly folded anti-formal structures. The basement rocks of Belaga Formation are all remarkably similar and of sandstone-shale laminated turbidite (Hutchison, 2005).

Several plunging folds can be observed in the Tatau area (Fig. 2.3) including the Arip-Pelungau Anticline and Buan Syncline which plunge ESE and can be used to determine the relative younging direction of the formation. The oldest formation in the area is the Bawang Member of the Belaga Formation and the youngest is the Quaternary alluvium that covers the river valleys and coastal areas. The distribution of the rocks in the core of the Arip-Pelungau area where the anticline plunges ESE is composed of rocks of the Bawang Member of the Belaga Formation. It consists largely of low grade meta-pelite, slate and quartzite (Wolfenden, 1960; Kirk, 1957; Hutchison, 2005). The Bawang Member is unconformably overlain by the Middle Eocene to Oligocene Tatau Formation. The contact between them can be seen at Ransi Hill and Tutong Hill.

The Belaga Formation is surrounded by the younger formation, i.e. Tatau Formation and Nyalau Formation along the Anak-Nyalau Fault contact. Most of the Ransi Member exposure is near the contact of Belaga Formation. The Belaga Formation had been subjected to intense folding and low grade metamorphism.

The gentle ESE plunging syncline in the Buan area at the centre and southeast of the Tatau area is occupied by the youngest strata of the mainly sandy Nyalau Formation. The Nyalau Formation has been interpreted as deltaic deposits dominanted by sandstone channels, lower coastal plain muds and coal deposits (Kamaludin Hassan, 2004). The folded-strata has been cut by the Anak-Nyalau Fault that trends SW-NE (Fig. 2.3).

The Middle Eocene to Oligocene Tatau Formation is estimated to be made up of over 2,500 m of clastic sediments with minor carbonate (Kamaludin Hassan, 2004; Leichti et. al., 1960; Wolfenden, 1960). It has within it two distinct members ie. (1) a Middle Eocene to Oligocene Ransi Member and (2) a Middle to Upper Eocene Arip Limestone Member. Deposition of both these members took place simultaneously in different environments.

The oldest unit of Tatau Formation is the Ransi Member. It is exposed in Tatau area at Ransi Hill, Tatau Hill, and Tutong Hill. It is made up of about 20 to 30m of moderately thick bedded (1-2m) sandy conglomerate and sandstone with very thin bedded, light to dark grey shale. Some of the sandstone beds contain burrows indicative of deltaic to shallow marine of deposition.

The Ransi Member is made up of 3 lithofacies: (1) thick bedded, coarse grained conglomerate in the lower part; (2) thin to medium bedded coarse grained, bioturbated sandstone in middle part and (3) medium grained, cross bedded sandstone in the upper part. The lower contact with the underlying Belaga Formation is an angular unconformity while it grades upward into the rest of Tatau Formation.

The Arip Member consists of about 200m of conformable passage beds, comprising dark greyish carbonaceous shale interbedded with mud to limestone near the top. The lower part of the Arip Member that is less fossiliferous is exposed in the Arip Valley at the Nursery Farm, whereas the richly fossiliferous upper part with calcareous algae and foraminifera is exposed in the Arip River Cave area (Fig. 2.3). The transitional zone sediments of this member grade into greyish to brownish argillaceous shale of the Tatau Formation in the Lesong area.

The post-Sarawak-Orogeny Upper Eocene and younger strata belonging to the Tatau, Nyalau, and Buan Formations in the Tatau area were deposited under shallow marine to non-marine conditions (Kamaludin Hassan, 2004; Hutchison, 2005).

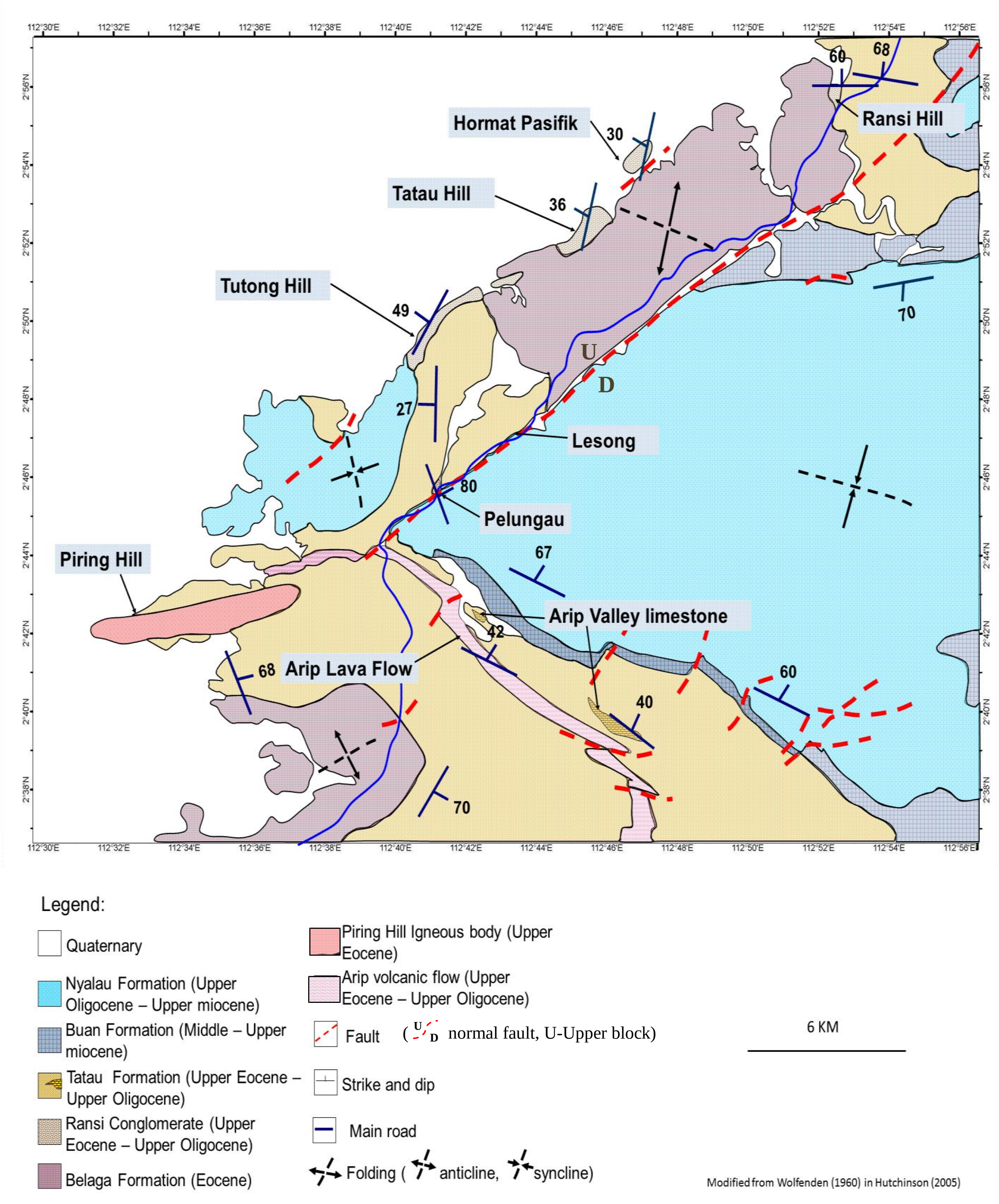

Fig. 2.3 Geological map with major structures of the Tatau area.

2.3 STRUCTURES OF TATAU AREA

There is a major NE-SW trending Anak-Nyalau Fault passing through the Tatau area (Fig. 2.3). The sense of faulting in the Tatau area is unknown but the part of the Anak-Nyalau Fault had been classified as a thrust fault by Mazlan (1999). Other smaller scale faults that had been identified in the field or from lineaments in the topography suggest that they are mainly aligned parallel to the major fault.

At the north of the Tatau Hill and Tutong Hill areas, the sense of dip slip fault has been interpreted as normal fault and the downthrown wall has been filled with recent Quaternary sediments at the southeast. The Anak-Nyalau Fault that passes through the core of Tatau area forms an uplifted area with older rocks exposed to the north and south west of the fault. This fault can be seen in the field near the Hormat Pasifik Quarry site as a zone of intense and chaotically folded and faulted zone (Fig. 2.3).

The fault in this area is a normal fault rather than a thrust fault because a synclinal fold was formed in the hanging wall of the fault. The Anak-Nyalau Fault dips to the southeast. The parasitic faults strike NE-SW and have high angles of dip of around 80° SE.

The strikes and dips of several beds are used to interpret the regional geology of the Tatau area. The beds of the Tatau Formation strike north-south and dip towards the west in the southwestern part of the area. The beds in the northeast trend E-W and dip towards the north.

This suggests that the northeastern side of the Anak-Nyalau Fault had undergone open anticlinal folding with the oldest part of the formation in the core and younger beds away from it in both the limbs.

The Nyalau Formation is surrounded by older formations, such as the Buan Formation and Tatau Formation in the southwestern of the Anak-Nyalau Fault. It is further away from the Buan Formation. There is a synclinal open fold which beds are younging towards the axis with relatively older Tatau Formation distributed in the outer parts of limbs. An anticline has being identified in the south of the Arip area that plunges NNW (Fig. 2.3).

The dips of the beds in the Tatau Hill and Hormat Pasifik Quarry suggest that the open anticline plunges towards the NW. Erosion has led to the exposure of the less resistant Belaga Formation as lowland surrounded by the Ransi Member which is more resistant and forms the hills next to it.

There are several relatively smaller scale faults oriented perpendicular to the Anak-Nyalau Fault in the area. The sense of these faults is unknown. They are located near Ransi Hill and Tutong Road. The faults were formed probably as a result of removal of the overburden during uplift and erosion causing the rocks to rebound with brittle deformation at shallow depths.