THE REGOLITH OF THE PURARI DELTA AND ADJACENT THRUST BELTS IN PAPUA NEW GUINEA: A PROMISING OIL SEARCH AREA

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Little has been written about regolith in oil producing areas because surficial geology masks the underlying oil bearing strata. In the western Papuan Basin, however, oil and gas seeps at the surface indicate promising targets below. Surface evidence of a subsurface mudstone diapir suggests a possible target around the margin of the eastern Purari Delta and the northerly striking "Aure" thrust belt, where oil and gas seeps are most abundant. It just so happens that a land research survey was conducted over this area (Ruxton *et al.* 1969). In hilly country drainage, texture and density identify units as they do in oil search (Slater & Dekker 1993).

To the west of here the margin of the Papuan Thrust Belt (which strikes west-north-west) adjacent to the Foreland Basin of the eastern Fly Platform hosts a major new oil field. Many authors suggest that the "Aure Thrust" is just the Papuan Thrust bent southwards (Figure 1). Oil and gas are also found to the south of the Gulf of Papua beneath the sea. Vigorous oil search is still being carried out by surface mapping, remote sensing and seismic profiling to site deep bores which are drilled to over a thousand metres hopefully to intersect oil plays in the Jurassic to Miocene strata often unconformable below the Neogene succession.

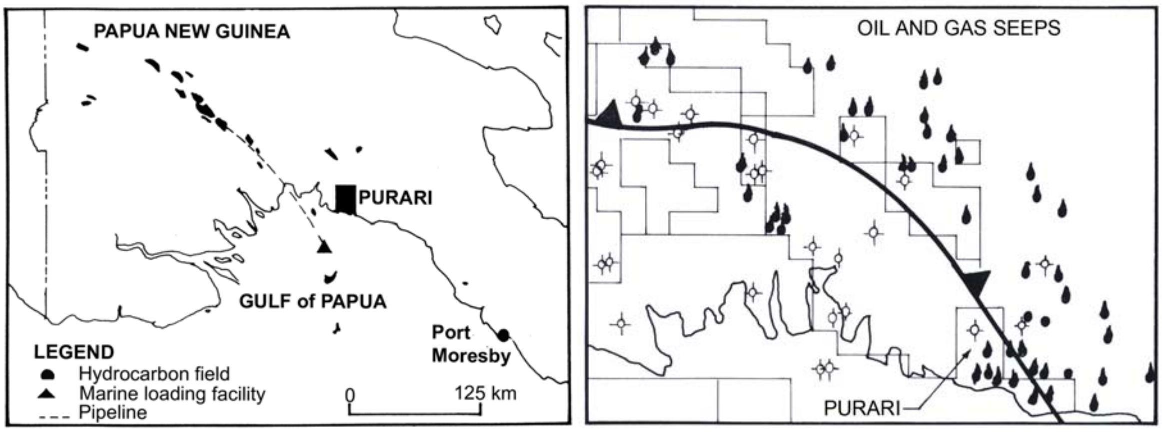

Figure 1a (left): Oil Fields of the West Papuan Basin as at 1993 and location of Figure 2 (black square). **Figure 1b (right):** Oil and Gas seeps in the West Papuan Basin.

Since, the land system survey the whole of the Purari River catchment has been studied for its hydroelectric potential (Petr 1983). The coastal fringe of the Gulf of Papua has also been described recently (Walsh & Nittrouer 2004).

THE FORELAND BASIN

The eastern Fly Platform is a lowland of composite alluvial plains assembled by several through-flowing rivers. Beyond the bay line (the junction between fluvial and intertidal) the grain size decreases largely to mud, the sediments are cyclically bedded laminae and prominent levees and crevasse splays disappear (Allen & Castaing 1993). The delta is naturally divided into four easterly trending zones (Figure 2). The coastal fringe of both active and buried beach ridges has smoothly curved outlines shaped by ocean swells causing north-westerly long-shore drift of sand. From the coastal sandy beach ridges to the inland there is a transition from salty mangrove, brackish nypa to freshwater vegetation on intertidal mud flats. It is a progradational sequence resulting from gradual build-out of the coast. The mangrove sequence is *Avicennia-Sonneratia* adjacent to the sea then *Rhizophora-Bruguiera* on the saltwater tidal flats and *Heritiera* furthest inland. (Alele 1 and Nipa 2 land systems). The freshwater sequence going inland is organic soils with either mid-height swamp forest (Purari 3) or swamp woodland (Murua 4) then on uppermost tidal flats with open canopy of mid-height trees Ebala (5). The latter can be transitional to non-tidal accreting alluvial plains (15 and 16) with fine textured soft alluvial swamp soils with sago palm. Also as the beach ridge barriers grow seawards their inland margins degrade by tidal creek scour and convert into tidal flats with peat over sand.

In: Roach I.C. ed. 2005. *Regolith 2005 – Ten Years of CRC LEME.* CRC LEME, pp. 283-288.

This merges into muck over clay. Continuing sand deposition out in the sea is shown by double linear bars adjacent to the western passage. Some of the sand is mineral grains, some clay grains and some pseudo-sand from soil profiles in the composite alluvial plains (Smith & Humphreys 1991).

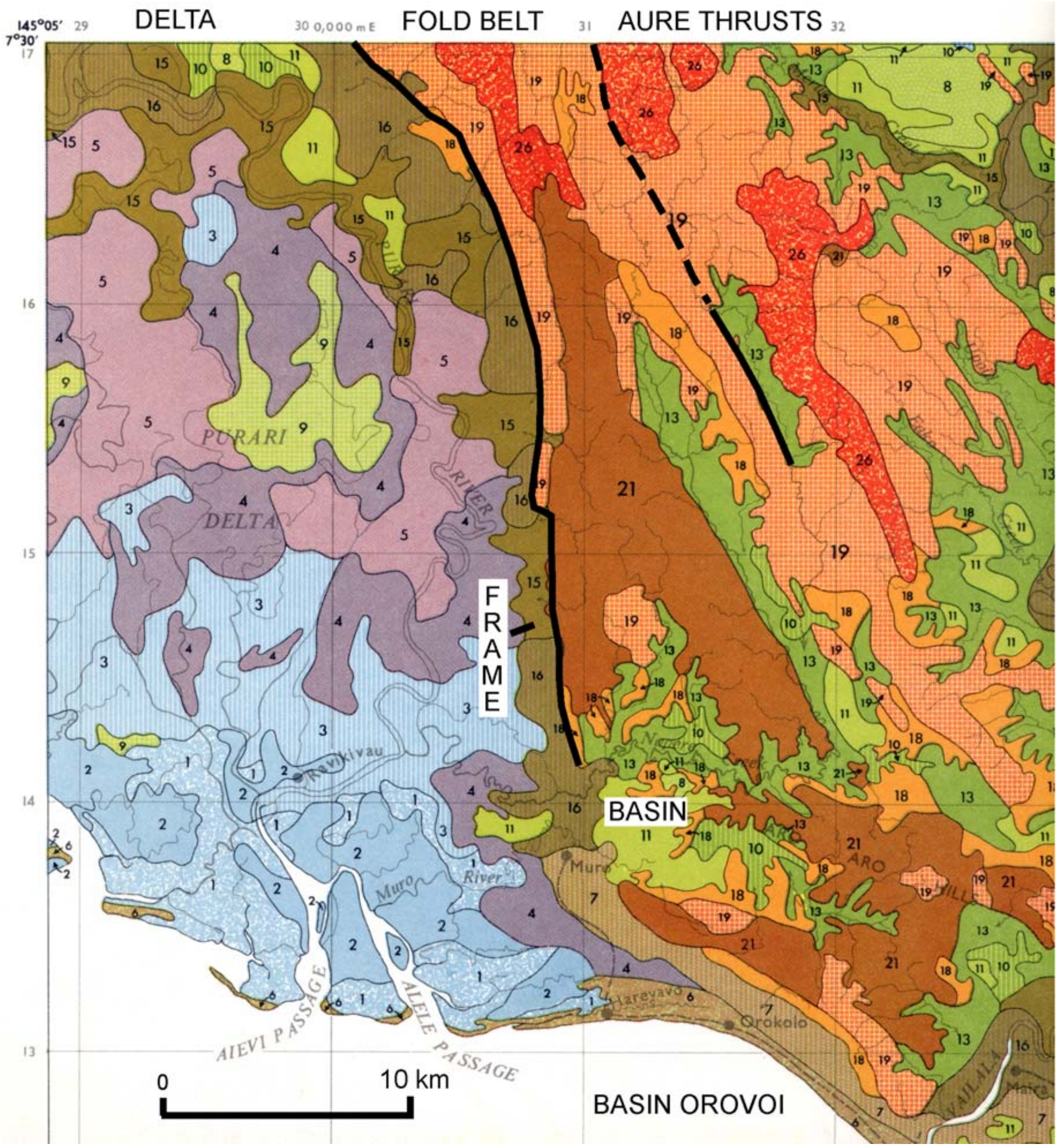

Figure 2: Land system map of the study area (8, 9, 10, 11 swamps, 13, 14 alluvial plains; all in the Orovoi Basin).

An important feature of the delta is that most of the intertidal mudflats have raised rims built up by crabs up to 50 cm above high tide levels (Wall 1964). The protruding parts are freshened by rain so that they can bear garden vegetation (coconut, taro, bananas, etc.). In places mounds coalesce to form small islands up to 3 x 5 m across. Sediment can be brought up to the surface from two metres below. Where this is pebbly as at Kerema, diamictites are formed which may be confused with debris flows. The whole delta was described as an abandoned tide-dominated plain by Woodroffe (2003), but there are no lagoons that would signify a deficiency of incoming sediment. At present there are three main distributaries emanating from a single point. There are also traces of former distributaries, some with crevasse splays. The whole delta plain has a very low gradient consistent with its fine grain size (of 1 in 10,000). The shallow stratigraphy is only partly known but seems to be a drape of laminated mud several metres thick over mud with sandy interleaves. Peat is common especially in the anoxic centres of the mud intertidal flats. Sulfaquents occur with secondary framboidal pyrite. Occasionally microloading in the form of convolutions may disturb the bedding (Walsh & Nittrouer 2004) and flaser structure is common. Typical sedimentation is shown in Table 1.

Table 1: Sedimentation of Eastern Purari Delta.

Sand	Laminae Sand/Clay	Laminated Clay
Bed Load	Rhythmite[1]	Slack Water
Barrier	Low Levees	Drape[2]
Off Shore	Intertidal	On Shore
Main Channels	Interconnectors	Tidal Flats
Flow up 2m/sec	Logs	Muck[3]
Thom & Wright 1983	Walsh & Nittrouer 2004	Shaw & Arthurton 1988

1. Couplets 2-4mm 2. Top Clay 2-6m thick 3. A lot of storm debris

WAIGANI LAND SYSTEM (No. 9)

The slightly raised, central stagnant freshwater swamp has herbs (*Hanguana malayana*), sedges (*Mapania macrocephala*), and ferns (*Cyclosurus sp.*). Its raised status may be due to: (1.) distance from tidal channels; (2.) similarity to a peat dome, due to higher productivity of sedges (Phillips & Bustin 1996); or, (3.) an erosional remnant of former alluvial strings, lobes and splays from a former high sea level. It could be comparable to the slightly higher ground around the bay line (Loffler 1974).

SEA LEVELS

In stable tectonic areas coral studies show that only small oscillations in sea level can have been expected in the Holocene (Thompson & Goldstein 2005). In the Sepik area of Papua New Guinea a higher sea level of 1-2 metres occurred in the mid-Holocene (between 6000 and 3000 years ago; Swadling *et al.* 1989). A similar rise would explain both high levees and the Waigani land system (Ravilious 2005). Peat domes on the coast north of Popondetta may be comparable (Koena Land System; Paterson 1964).

THE EASTERN HALF

The eastern edge of the delta has a narrow margin of alluvial plain, like a picture frame, on the outer side of which is the north-south "Aure Thrust" fault. Some see this as an extension of the Papuan fault which is a passive duplex fault (Hobson 1986). To the east of the fault are a series of north-north-westerly trending strike ridges of Upper Pliocene to Lower Pleistocene mudstone, siltstone and sandstone. They bear soils of orthic dystochrepts and typochrults; earth flows are common on bentonite patches of mudstone. In regolith terms the dystrochrepts are deep, generally uniform clay loam (but range from loam to sandy clay). B and C horizons have mottles of completely weathered rock fragments. The typochrults have brown thick (12-50 cm) A_1 horizons with clay loam textures overlying thick (25 - 100 cm) yellowish red to red clay to clay loam B_2 horizon, locally with common light grey mottles. They have developed on greywacke mudstone with an average andesite composition. The boundaries of the land systems are mapped by photo interpretation of the landform and vegetation. The vegetation is usually primary tropical rain forest. Several auger holes typify each land system. Thus, dystrochrepts are typical on steep slopes of both Maipora (19) and Aro land systems (21), whereas typochrults typify Hauta land systems (18) on moderate slopes.

OIL SEARCH

In 1911 oil seepages were discovered near the mouth of the Vailala River. Later, three dry deep bores were drilled at Horohoro and Upoia. To date twelve bores have now been completed without finding commercial deposits. However, economic oilfields have been found to the north and west northwest and in the Gulf of Papua (gas). Successful wells are mostly in the Papuan thrust and fold belt in Jurassic non-bioturbated sandstones. Some discoveries were made with surface mapping, remote imagery and wildcat drilling. In the foreland province in the south structures are hidden and sealed beneath Miocene and Pliocene strata.

Regolith mapping in the mid-Orovoi Basin, based on landform and vegetation, shows a complex of land systems of small areas in a chaotic pattern. They are in the northeast quadrant of two crossing faults (N-S, E-W), which may have been activated at the same time causing break up of strata. They also lie within the area of most oil and gas seeps. So, gas escape can be a factor (Fulthorpe & Austin 2004), but the presence of an eroded shale or mud diapir in a melange is a strong possibility (Van Rensbergen *et al.* 1999). A diapir may be an oil source target. The surrounding tectonic pattern resembles a pair of pincers facing each other across the fault, the centre region in between being a circle enclosing an unlikely composite grouping of land systems. A comparable pattern of compressional growth structures and diapir in a basin occurs in the La Popa Basin in northeast Mexico (Millan-Garrido 2004), where the diapir is composed of evaporites not shale. The pincers would have been prised apart (pushed aside; Brown & Grange 1993). Other similar chaotic terrains are figured in "subsurface sediment and mobilization" (Geological Society, Special Publication 216, pages 145, 251 and 454).

The surface pattern of the Aro hills (Aro land system 21) is also very similar to that of the Puri oilfield 50 km to the north where a trianglular zone of deformation occurs at the leading edge of the Papuan Fold Belt. The analogy is made closer by the presence of a circular basin (Suai Basin). The two triangles are of similar size (Figure 3). If the Aro hills triangle is superimposed on the Puri triangle the Horohoro bores would be in a similar position to the Puri number 1 bore. The Bounding fault of the Papuan Fold Belt does swing round to the south. The boundary of the "Aure Thrust" zone comes in at the edge of the Lohiki land system (26, Fig. 2). The high hills of the Lohiki land system had steep slopes with undifferentiated non-gleyed alluvial stony soils (Orthic Hapludents). The pattern of triangular thrust faults is also seen in oilfields in Canada, Russia, Pakistan and France (Medd 1996).

The structural framework changes and is updated as deep mapping proceeds. Here we show (Figure 2) a thin wedge of the Papuan Fold Belt between the delta and the Aure Thrust Zone, based on land system mapping; recent exploration confirms this (Parkin *et al.* 1996).

Terrestrial regolith oil search in the 1970's measured ethane to pentane. Anomalous high values were differentiated from background populations of low values. Today sophisticated organic chemistry of oils is used to give type, maturity and possible maturation. In west Papua, early medium gravity oil was displaced by later gas and condensate.

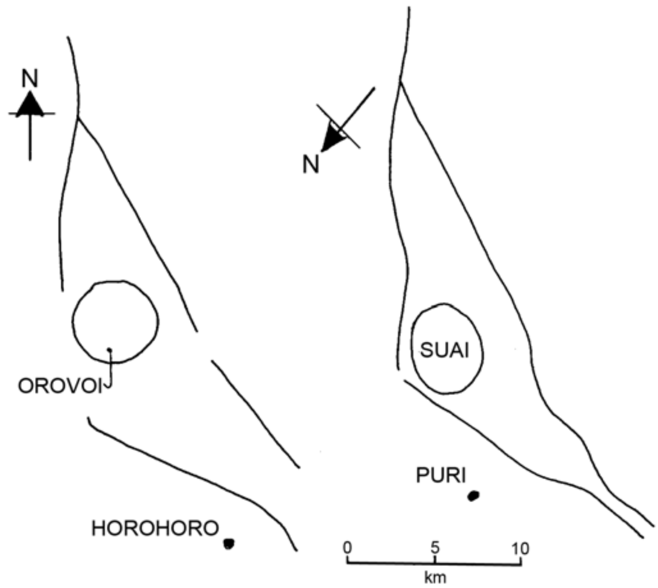

Figure 3: Triangle zone deformation at the leading edge of the Papuan Fold Belt. The circles enclose central basins.

In the Aure Thrust area hydrogen and oxygen indices of kerogen (organic matter) in nearly fresh fragments in regolith of older sediments can indicate organic maturity. Burial of sediment was followed by catagenesis. Later erosion to the near-surface was followed by diagenesis (usually slight oxidation). Gas seeps are scattered and thin coal seams occur in Miocene strata.

DISCUSSION

In the Purari Delta there can be malodorous mud, paludal clay histosol and peat at the surface. Laminations of mud and organic layers occur. Thin laminae (2.5 mm thick) of alternating mud and sand are found beneath channels and deposition averages four pairs a year (Walsh & Nittrouer 2004). Oil seeps in the regolith in the Papuan Fold Belt can indicate origins. Thus, at Upoia oleanane and bicadinane are from angiosperm plants (dipterocarps). The source is probably coaly shale of Oligocene terrestrial sediments (Waples & Wulfe 1996).

There is a contrast between north and south Papua New Guinea. In the north the regolith on the coast adjacent to the small Musa River Delta is micaceous alluvial silt over find sandy top-set beds of a Gilbert-type delta on a rising coast (Ruxton *et al.* 1967). Whereas, in the south around the Gulf of Papua, there is a mud drape on the subsiding coast.

The whole Purari Delta with its square shape radial distributaries and stress field is similar to the Baram Delta in Brunei (Tingay *et al.* 2005). Its sediment wedge is large enough to have subsurface structures such as listric faults and mud diapirs. Thus, some photo lineaments, traces and land system boundaries may have structural significance (Paijmans 1970). Diapiric chloritic mudstones in anticlines were noted in the Aure Group by Hill and others in 1990 who associated them with either extensional faults or back thrusts.

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