FIELD TRIP GUIDE
TO

(A) THE UPPER CRUSE FORMATION AT ANGLAIS POINT, PALO SECO

(B) THE PALO SECO AND ANGLAIS POINT MUD VOLCANOES

August 25th 2002

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The Upper Cruse Formation at Anglais Point, Palo Seco

<u>Cruse Formation</u> *(after Suter 1951)*

The type locality is in the subsurface of the Cruse and Forest Reserve oilfields. Well CR 141 is the type location with a thickness exceeding 2600 *ft.* FR 670 is the co-type locality. The lower boundary is transitional to Lengua, while the upper boundary is locally strongly unconformable to Forest. There is clear evidence of unconformity in the Apex field (claystone pebbles pierced by Pholas - Kugler). Electric logs of the Forest Reserve field show progressive overlap of Forest clay and stray sands over various Cruse sands. The Lower Cruse is dominantly clayey, the middle and upper parts are sandy. Individual sand layers may be over 100 ft. (30 in.) thick. In the Barrackpore area Cruse sands are absent. The sand content of Cruse increases westwards and especially south-westwards, and numerous sands of the Erin Basin are missing at Fyzabad. The Lower Cruse clays can now be identified on the basis of foraminifera all over South Trinidad.

Characteristic foraminifera are *Discamminoides tobleri* Bronnimann, *Guppyella miocenica* (Cushman), and *Alveovaloulina suteri* Bronnimann.

The Cruse-cycle sand distribution is shown in Figure 7. (Barr, Waite & Wilson 1955)
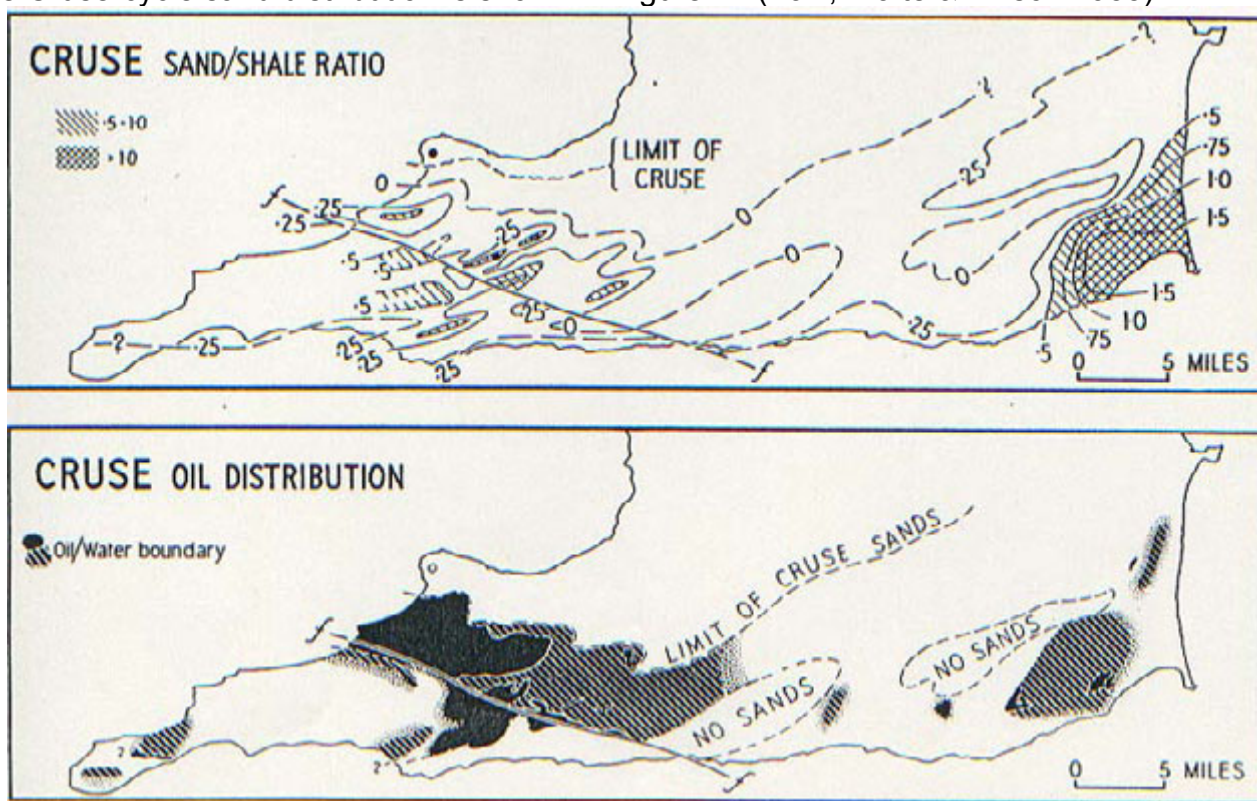

Fig. 7.—The Cruse cycle, showing sand/shale ratio (upper) and oil distribution (lower).

There is a strong development of sands in the southeastern Guayaguayare area with a rapid reduction in sand content toward the pre-Miocene uplifts of the Southern Range trend. Sand content appears low over the central area with a sand/shale ratio below 0.25, and then well-defined trends of higher sand content reappear in the western oil field district. These trends are elongate, showing a general east-northeast to west-southwest alignment, and have well-defined maxima with sand/shale ratios more than 0.5. The sands die out completely along the northern rim of the basin, and in the western oil field district the entire Cruse cycle wedges out against the rising pre-Miocene uplift in the La Brea area. As far as can be traced, similar sand trends seem to occur southwest of the Los Bajos fault, but farther west in the Erin syncline well data are lacking.

These trends suggest the possibility of two sources of sedimentation—one from the east and southeast bringing in the predominant sand deposition of the Guayaguayare area, and a second source, less rich in sand, from the west-southwest, supplying sediments to the Erin-Forest areas.

In the western oil field district there are three main areas of oil accumulation, the Forest Reserve-Point Fortin, the Los Bajos fault zone, and the Palo Seco areas, as shown in Figure 7.

The Forest Reserve-Point Fortin area shows a well-defined water line along the south flank of the Forest anticline swinging around the eastern nose of the structure, forming a narrow watered zone between the fold axis and the edge of the sands. Farther west in the Point Fortin vicinity the Cruse sands may be oil bearing in their entire extent from the Los Bajos fault to the sand edge on the north. This appears to be the result of a combination of stratigraphic and structural factors, the overall northward wedging of the sands which is primarily responsible for the oil accumulation being modified by the structural elements of the Point Fortin and the Forest anticlines.

In the Los Bajos area oil occurrence appears to be the result of a combination of stratigraphic factors and fault-controlled accumulation along the Los Bajos fault. On the northern side there is a well-defined zone of oil accumulation almost in the bottom of the Siparia syncline probably related to the sand trend, but in which the fault trapping and fault migration also appear to play an important part. Farther eastward the oil acccumulation follows a zone roughly parallel to the Los Bajos fault and is almost entirely independent both of the southeastward rising flank and of the abutting sand trends. Despite this evident fault control, the Cruse oils along this zone appear to be indigenous Miocene oil types, although some redistribution by way of the fault plane has undoubtedly occurred. (Barr, *et al.,*. 1951). Rather similar conditions occur south of the Los Bajos fault.

In the **Palo Seco** area oil accumulation appears for the most part to be a purely stratigraphic-trap type, the oil being concentrated in lenticular sands in the south- ward- and eastward-rising subsidiary syncline which lies south of the Los Bajos fault. Drilling has not yet defined the water line in this area, the controlling factors in current development being deteriorating sand conditions. The south Palo Seco area may be regarded as an excellent example of stratigraphic-trap accumulation, as the entire Cruse and Forest sequences crop out to the south of the field.

Minor oil accumulations of lenticular-trap type occur at Penal and east of Palo Seco, whereas the small accumulation at Moruga appears to be related to severe faulting.
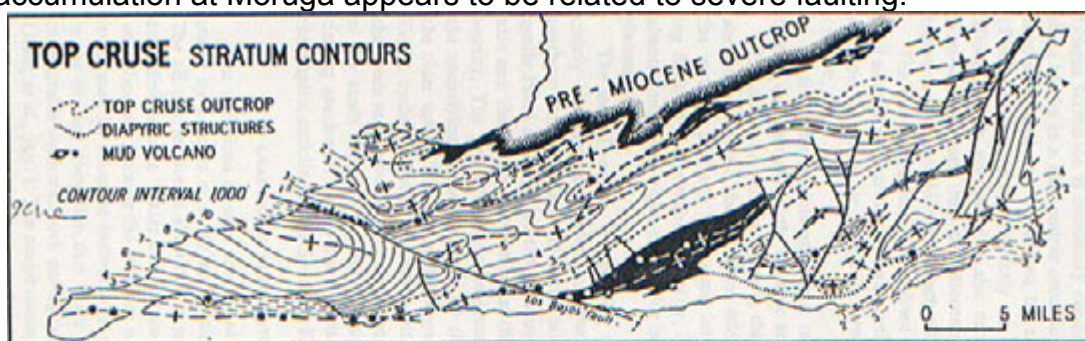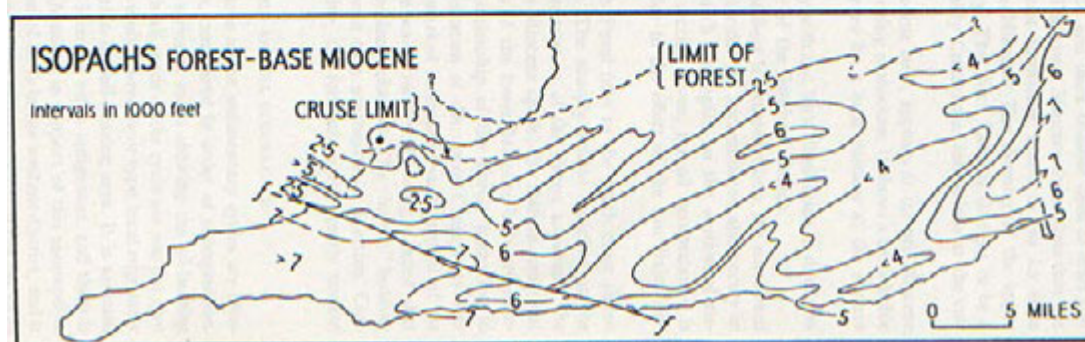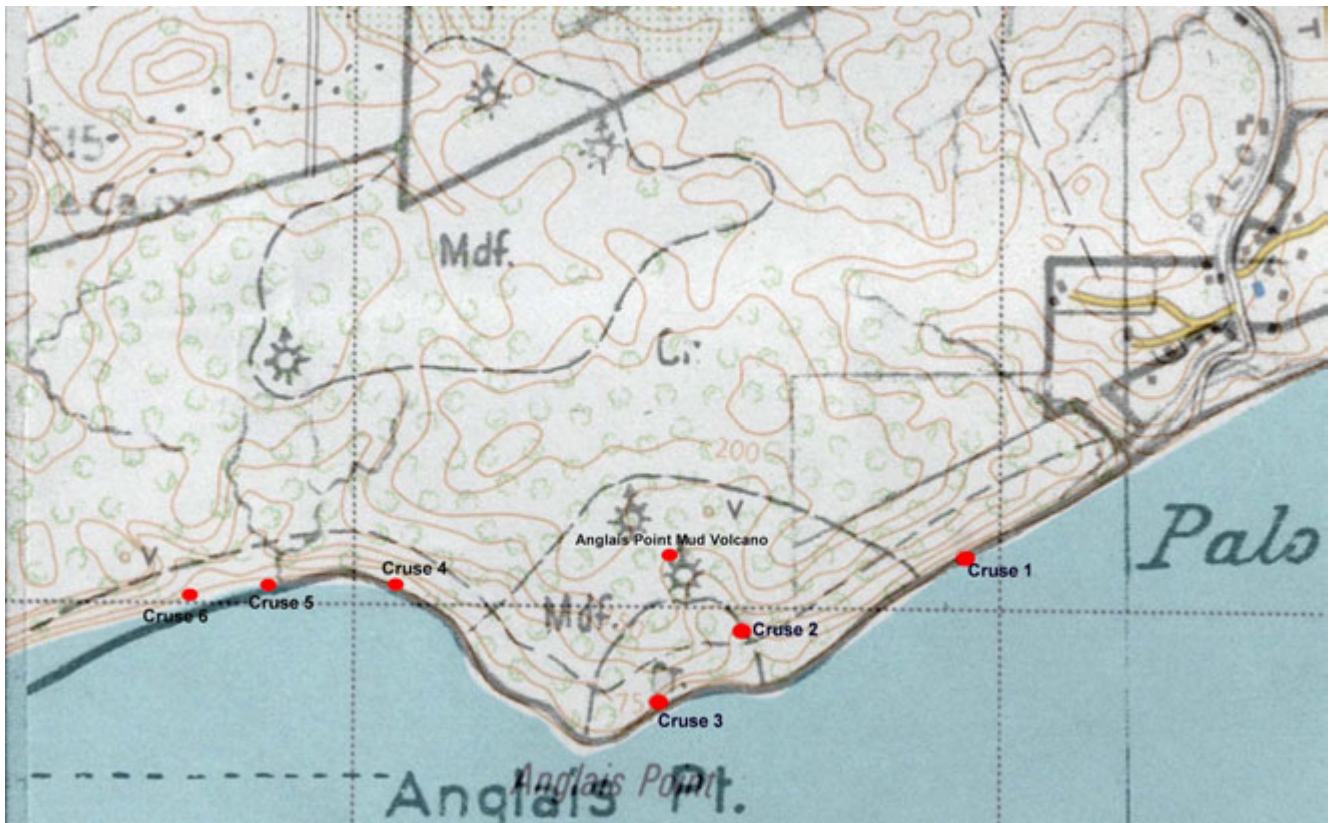

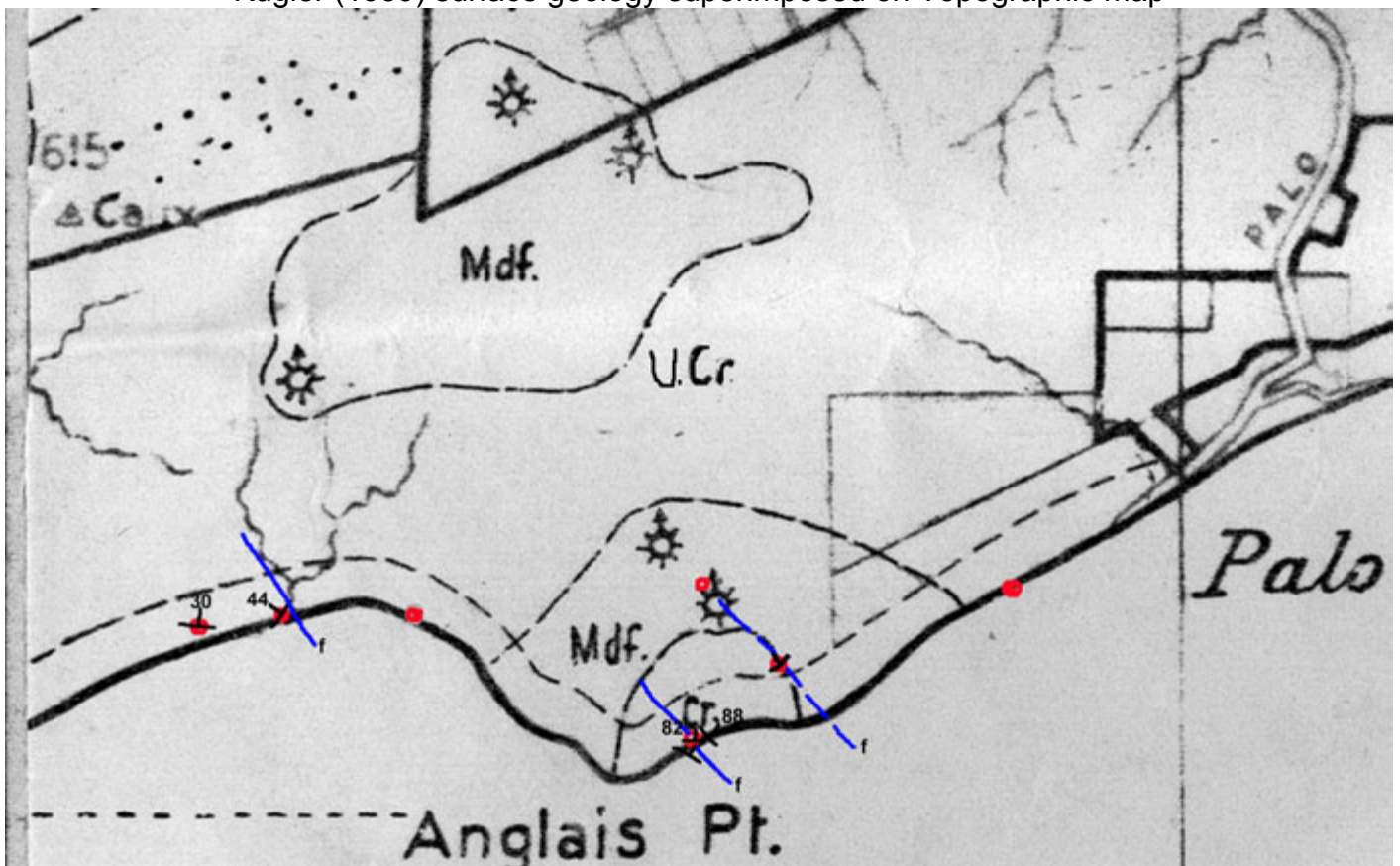FIG. 4.—Structure contours on top of Cruse formation.

FIG. 5.—Isopach map of the interval from upper Forest clay to base of Miocene.

3

Kugler (1959) surface geology superimposed on Topographic map

Modified Kugler surface geology map, after Archie

Cruse 1 stop - Location: UTM (Naparima datum) E- 0653952.354 N – 1113076.163
This outcrop is made up of alternating parallel laminated claystones and sands. Sand packages are 6 – 8" thick and individual units thin upward. The sand is very fine grained. Total absence of bioturbation.

Laminated claystones and siltstones with thin sand laminae. Some amount of channelisation is noticed as the base of one channel is lines with flat ,subrounded claystone fragments.
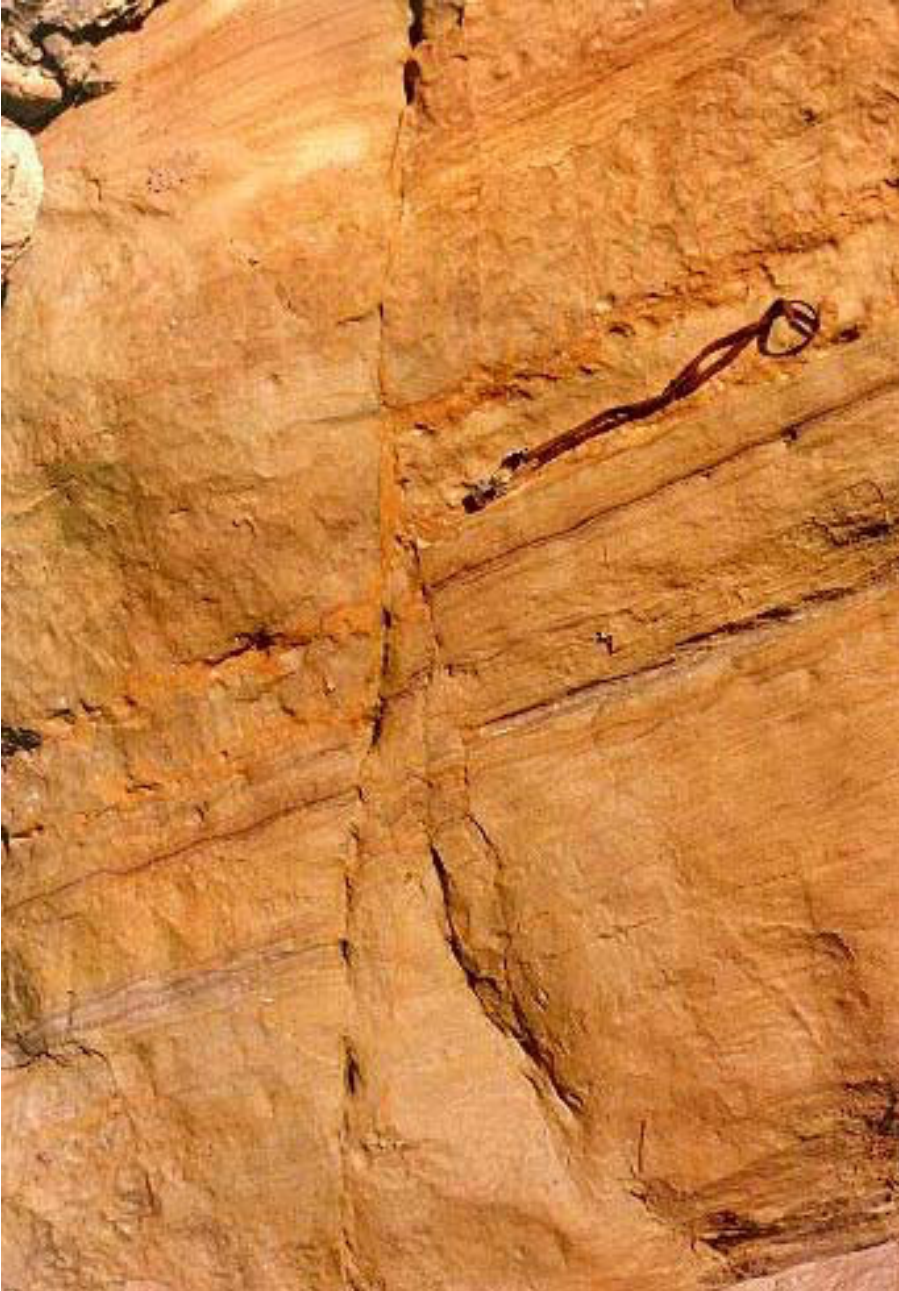
Sand, with normal fault, fault gouge and shale smear. Displacement is about 8".

Strike is $70^0 - 250^0$.
Higher up the section, strike is $24^0 - 204^0$, with beds being vertical.

Close up showing ripples sands at base, overlain by extensively bioturbated sands and silts, which are in turn overlain by cross laminated sands.

Cruse 3 stop - Location: UTM (Naparima datum) E- 0653475.408   N – 1112840.868

Almost vertical beds that have been affected by a combination of slumping and faulting. Dip, dip direction and strike change along this outcrop in response to faulting. The lower photo illustrates this change with what appears to be an anticline to the left. **Dip 1** - Strike 132^0 – 312^0, dip 88^0, direction of dip 15^0. . **Dip 2** - Strike 105^0 – 285^0, dip 82^0, direction of dip 15^0. A Pleistocene terrace is visible, its base is marked by large boulders.

Pleistocene Terrace

dip 1

dip 2

Dip 3 - Strike $130^0 - 310^0$, dip 82^0, direction of dip 40^0. This is a claystone dominated section with siltstones and minor sands.

dip 3

Cruse 4 stop - Location: UTM (Naparima datum) E- 0653059 N – 1113016
Bioturbated sand, burrows are predominantly vertical , smooth walled. A fault near vertical of unknown displacement cuts the section.

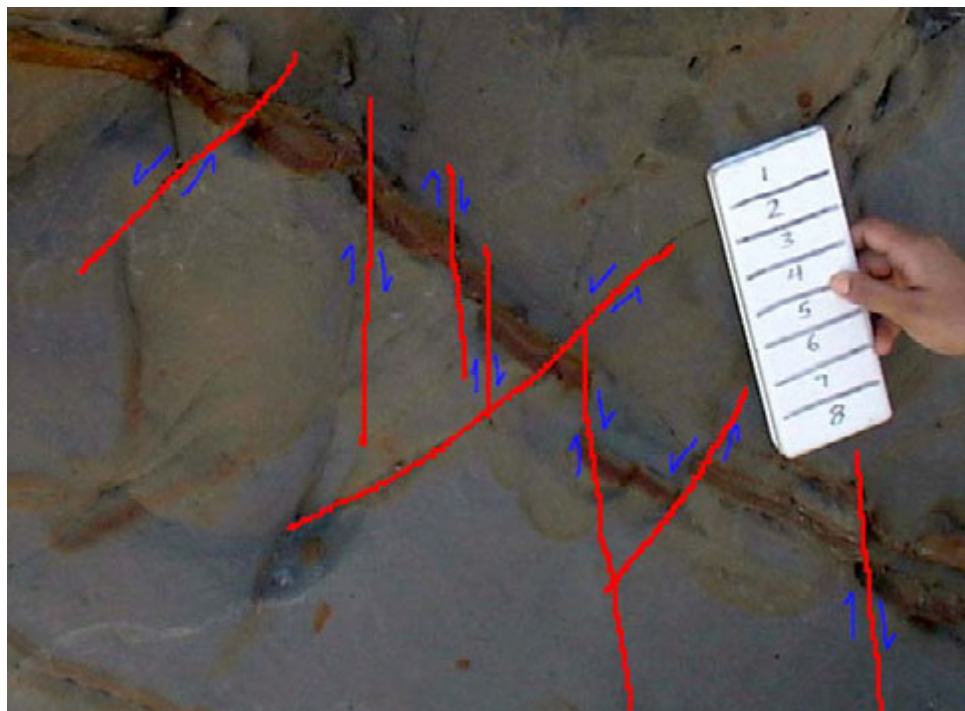Cruse 5 stop - Location: UTM (Naparima datum) E- 0652871   N – 1113043
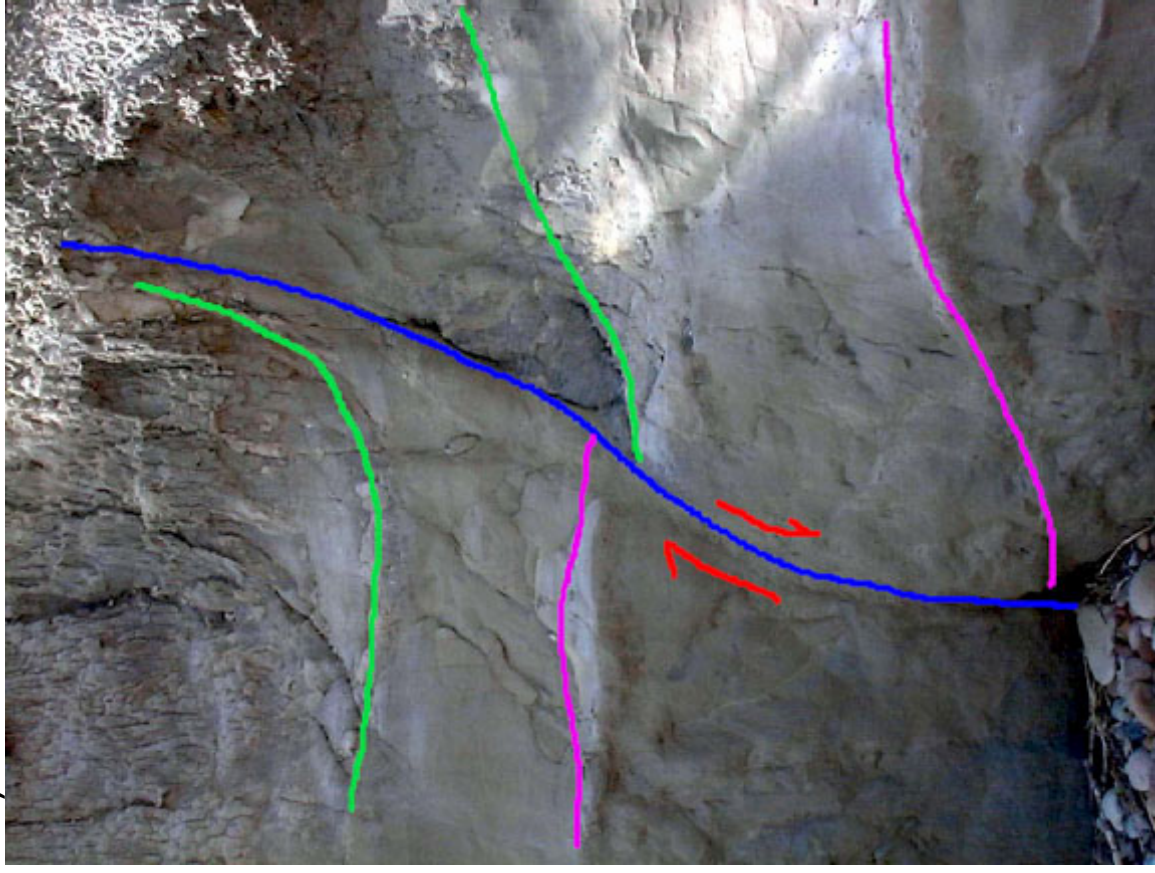
Reverse ? fault ,

Claystone concretions in a disturbed sand bed.

Strike $40^0 - 220^0$, dip 44^0, direction of dip 130^0. Small normal faults (2" throw) generally down to the east.

Interpreted close up of fault displacements

Cruse 6 stop - Location: UTM (Naparima datum) E- 0652676   N – 1113005
This section appears to be a mud dominated system with thin (< 5') sands.

The sand unit is 3' thick, has a sharp base and top, parallel bedded.

The sand is 5' thick and thins to the left (east) and disappears before the reaching the previous photo.

Schematic columnar section of the Cruse Formation exposed at Cruse 6 location

Normal fault, throw of 3" down to the east.

Normal faults, throw of 2" down to the east.

Flame structure caused by de-watering.

Strike 88^0 – 268^0 , dip 30^0 , direction of dip 358^0 . Sands are parallel laminated, Fine grained, abundant mica.

Current direction
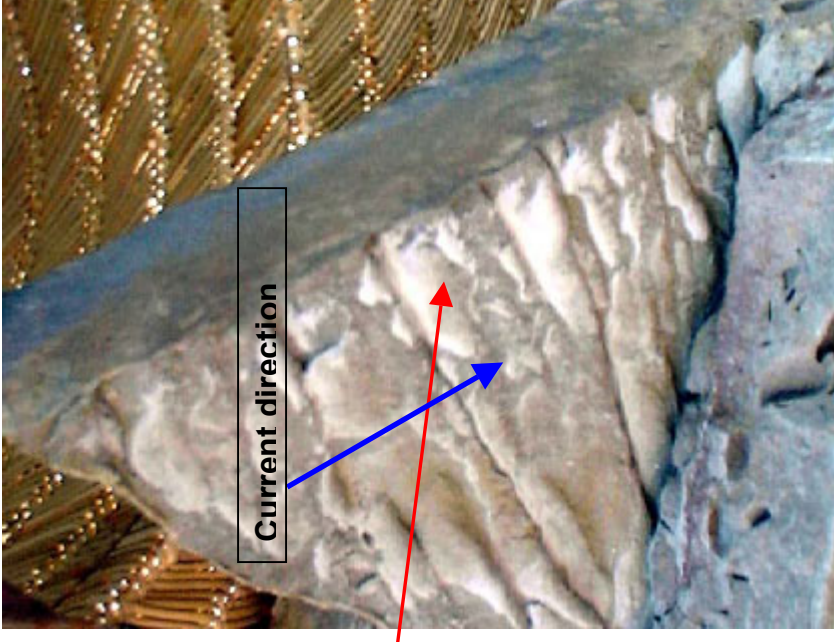
Close up of resistant bed. It is calcite rich (cement?).. The base appears to be moulds of ripples of the lower bed. If they are ripples current flow is perpendicular to the long axis and thus parallel to dip.
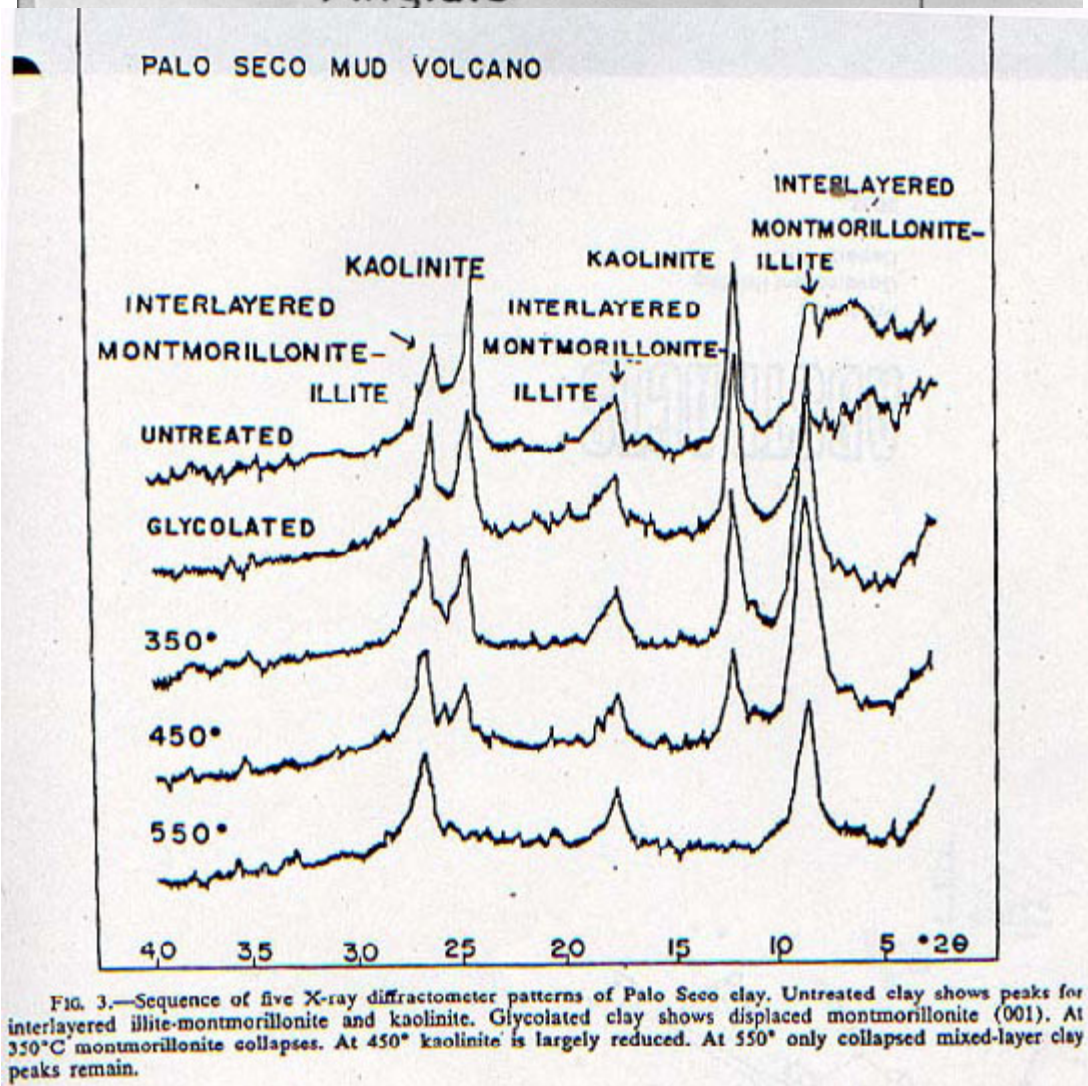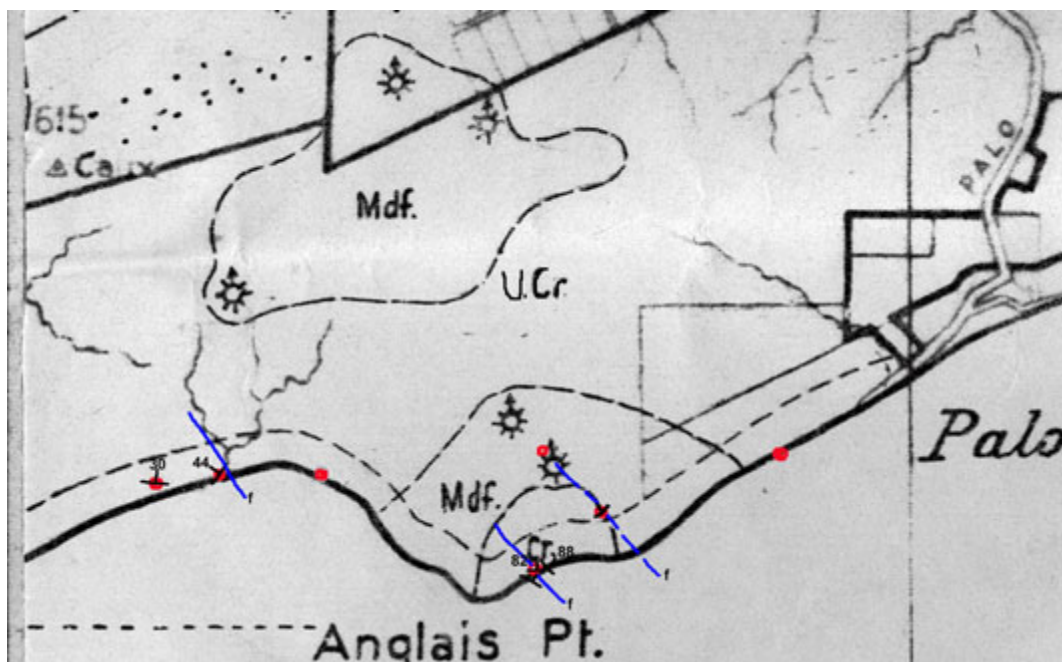
THE PALO SECO AND ANGLAIS POINT MUD VOLCANOES

The term "mud-volcano" generally is applied to a more or less violent eruption or surfaces extrusion of watery mud or clay which almost invariably is accompanied by methane gas, and which commonly tends to build up a solid mud or clay deposit around its orifice which may have a conical or volcano-like shape. The source of a mud volcano commonly may be traced to a substantial subsurface layer or diapir of highly plastic, and probably undercompacted, mud or shale. Mud volcanoes also commonly appear to be related to lines of fracture, faulting, or sharp folding. There appears to be a close interrelation between undercompacted (overpressured) muds or shale bodies, mud or shale diapirs, mud lumps, and mud volcanoes; and all degrees of gradation from one to another. Mud volcanoes are one of the most useful surface sources of information on the nature of materials in mud diapirs and undercompacted shale bodies.
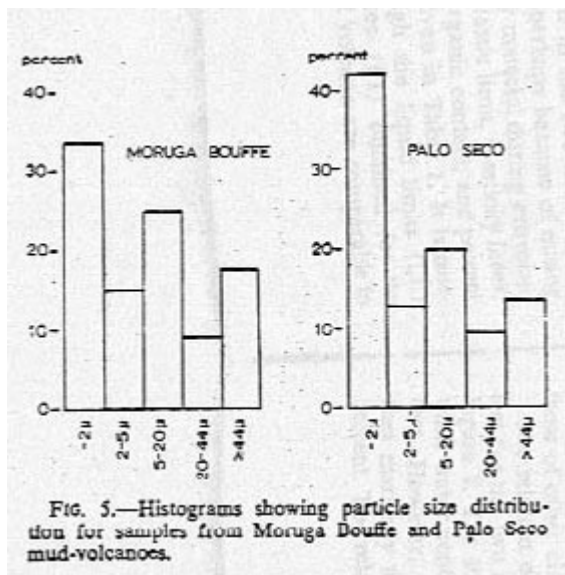
The motivating force responsible for a mud volcano is, in part, simply the weight of rock overburden borne by the fluid content of undecompacted shales. However, mud volcanoes all over the world are associated so invariably with quietly or explosively escaping methane gas that it is reasonable to conclude that the presence of methane gas in the subsurface is also an essential feature of the phenomenon. The mud of the volcanoes is a mixture of clay and salt water which is kept in the state of a slurry by the boiling or churning activity of escaping methane gas. Probably the methane gas was derived either directly from organic matter in muds or shales or from secondary accumulations in sand stringers within the source-rock shale or from larger reservoirs just above or just below such shales. Some liquid oil often, but not always, is associated with the hydrocarbon gases of mud volcanoes.

Commonly the activity of a mud volcano is simply a mild surface upwelling of muddy and usually saline water accompanied by gas bubbles. However, many ,instances are known of highly explosive eruptions where large masses of rock have been violently blown out hundreds of feet into the air and scattered widely over the countryside. These intermittent violent eruptions strongly suggest that motive force is not merely weight of gradually increasing overburden but is due to periodic buildup and release of internal pressure from the generation of methane gas within the shale body or diapir.

PALO SECO Mud Volcanoes:

location N 121,000 , E 284,000 (Cassini links), Area – 0.5 hectacres, 75 m in diameter. There is negligible tassik in this area and the cones are found in thick bush, surveys show that the mudflows cover 24 hectacres. No pebbles or boulders are seen around the eruptive centres.

FIG. 3.—Sequence of five X-ray diffractometer patterns of Palo Seco clay. Untreated clay shows peaks for interlayered illite-montmorillonite and kaolinite. Glycolated clay shows displaced montmorillonite (001). At 350°C montmorillonite collapses. At 450° kaolinite is largely reduced. At 550° only collapsed mixed-layer clay peaks remain.

The coarser particles microscopically appear to consist of fine quartz.

Fig. 5.—Histograms showing particle size distribution for samples from Moruga Bouffe and Palo Seco mud-volcanoes.

Water analysis

PH	9.3	HCO_3	214
Cl	10,800	Fe	1
SO_4	12	Ca	4
CO_3	600	Mg	56
Total Solids	17,090	Mud density lbs/ft^3	85
Viscosity	60	Equivalent ppm NaCl	18,493
Rw	0.325		

Gas Analysis

Acid Gasses – nil	Butane - nil
Methane – 97.3	Air – nil
Ethane – 1.0	Hydrogen Sulphide - nil
Propane - nil	Permanent gasses – 1.7

The gasses burn with a yellow to orange, smokeless flame. Deville et al (2002) indicate that the gas is thermogenic in origin. Analysis of noble gas radiogenic isotopes ($^{40}Ar^*/^{20}Ne$ vs $^4He/^{20}Ne$) has shown that the residence time is shorter for the gas expelled by the mud volcanoes than for gas present in producing fields. Thus gas expelled is not from fields but from deep kitchens.

This is the principal vent, it has been classed as a caldera type by Barr and Saunders (1974) There is a visible oil ring in the mud and a sheen on the surrounding mud. A gas bubble is seen approximately every 10 seconds.

Second vent, usually it is a cone about 4 feet high, but someone has removed the top. Mud issues from the vent with no set frequency.

ANGLAIS POINT

Location of main vent UTM (Naparima Datum) : E 0653489.642 N 1113095.624, Elevation 151.8 feet. Location according to Higgins and Saunders (1974) N 118,500 E 285,000 Cassini Links, Width of flow 60 m, length of flow 230m. Total mudflow exposure is 16 ha.

This is a single, shield type mud volcano on high ground at the back of the cliffs with a mud 'glacier' dropping steeply to the beach. Acitvity is minimal with minor cones (4" high), although historical records suggest violent eruptions in 1960 and 1906. Boulders, pebbles and sand grains are found on the surface of the mudflow, where the flow meets the sea, is found an apron of large boulders dominantly of composed of sandstone. The bulk of the clasts are of Cruse origin, some of the sands being oil impregnated. Herrera sandstones and conglomerates are the second most common type.

The closest oil production is from the Upper Cruse sands in Primera's PaloSeco lease 2km to the NE. The oil saturated sands strongly suggest potential reservoirs nearby, and the occurrence of Herrera sands is an exploration target.

Examples of mud vents

View of mud 'glacier' looking south. Visible in the middle is a large pressure ridge, it is found where there is a sudden change in the gradient of the 'valley'. In the foreground are down to the south extensional faults caused by a combination of mud being intruded at the top of the slope and erosion at the toe of the slide causing the slope to fail.

Main active mud vent

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