Trinidad-Gulf of Paria:
'piggyback' halite-dissolution basins (11-0Ma) on a long-lived foreland-basin thrust belt (Campanian-Recent)

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EXECUTIVE SUMMARY

According to the popular "Pindell Model", the Jurassic-Cretaceous passive margin of Trinidad persisted until as late as Miocene time, whereupon it was destroyed by the obliquely colliding Caribbean Arc arriving from the west, initiating a foreland basin in Trinidad. In contrast, an exhaustive synthesis presented here of literature published since 1860 clearly shows a S-verging, S-migrating foreland basin in Trinidad starting 70 m.y. earlier (latest Cretaceous). This basin can be attributed to the published concept of slow (amagmatic) Protocaribbean subduction under the N-facing former passive margin, from Campanian time, pushing a "Slope Nappe" (former passive-margin slope and underlying rift fill and continental basement) up onto the former outer shelf, metamorphosing the shelf and rift succession there, and driving the foreland basin. In turn these metashelf and metarift strata were uplifted in Miocene time, as an in-sequence "Shelf Nappe" (present Paria-Northern Range; Oligo-Miocene cooling ages), further eroding the covering Slope Nappe and forcing the basin south. Nappe mountains fed olistostromes and turbidites southward to this Protocaribbean Foreland Basin from late Campanian (Galera Formation) to early Late Miocene time (Lower Cruse), ahead of a generally S-jumping thrust front. These sediments were deposited as submarine fan-deltas on the northern "active slope" of a S-migrating flysch

trough, opposite a mud-rich "passive slope" and (beyond Trinidad) a presumed sandy southern shelf. The thrust front intermittently stepped back north, as shown by Central Range unconformities (*e.g.* sub-Nariva, sub-Brasso, sub-Tamana); other unconformities (sub-Chaudiere, sub-Cipero) record "pulling-in" of the forebulge due to changes in Protocaribbean relative motion.

The E-migrating Caribbean Arc "collision point" reached the longitude of NW Trinidad later (5 Ma, Pliocene, post-Lower Cruse) than stated by the Pindell Model (ca. 10 Ma), having begun its 1,100 km ESE (relative) transit along the Venezuela-Trinidad margin much later than the model asserts, starting from Guajira in the far west at 30 Ma (mid-Oligocene) rather than 60 Ma (Paleocene). This ESE motion obliquely along the ENE-trending Protocaribbean paleomountains of the central Venezuela-Trinidad sector of the margin caused oblique obduction of a Caribbean Arc nappe (incorporating the Villa de Cura Complex, Margarita and Tobago) onto the Slope-Shelf Nappe stack, through Early Miocene to Recent time (still in progress between the Margarita "suture point" and Tobago); thus the Caribbean took over diachronously as foreland-basin driver. The presently active (Caribbean) foredeep is confined to the far east (Deltana-Columbus Basin).

In Trinidad, Late Miocene (post-11 Ma) to Recent basins on the Caribbean-Protocaribbean nappe complex and its southern thrust belt (*i.e.* North Coast Basin, Gulf of Paria, Caroni and Southern Basins and their eastern-shelf continuations), interpreted in the literature as extensional or transtensional despite lacking volcanics, are reinterpreted here as synorogenic wedge-top basins, growing during nappe emplacement and shortening (ongoing). These are "pseudo-extensional" basins, formed by subsurface dissolution of a formerly unknown, thick (km), synrift, diapiric, lowermost Cretaceous halite interval in the Slope Nappe, Shelf Nappe and parautochthon, here named the "Carib Halite". In these basins, subsidence by buried-halite dissolution outweighs tectonic (shortening) uplift; subsequent reduction or cessation of halite dissolution (due to halite exhaustion?) has locally allowed uplift to overtake subsidence in Quaternary time (ca 1 Ma), forming the Central and Southern

Ranges. Massive underground halite dissolution coincided with the 11-0 Ma long-term glacioeustatic low (Haq), and reflects prodigious rainfall during each early-postglacial recovery, supplying fresh water to the subsurface along orogenically fractured aquifers connected to nappe- and thrust-belt mountain recharge areas.

The Carib Halite dissolution "weld" can be identified in wells and exposures, but the halite itself is nowhere exposed, and where thought to be preserved is beyond drilled depths. The halite was deposited during the late-rift stage in a graben system that reached westward from Trinidad through northern Venezuela to Colombia (Bogotá halite). The age of the Carib Halite, constrained by fossils in strata below and above the dissolution weld, is early Neocomian (specifically late Berriasian and early Valanginian). This age is consistent with the lack of any indisputably Berriasian faunas among the recorded Jurassic-Cretaceous fossils ever found in Trinidad and Venezuela, and coincides precisely with a major eustatic sea-level low (Haq chart), that provided the halite-depositing graben with the required isolation from the world ocean. The deduced Neocomian age of the halite indicates that rifting in Venezuela and Trinidad persisted much later than proposed by Pindell and co-workers, who argued that Protocaribbean rifting ended (sea-floor spreading began) 20-30 m.y. earlier in the Jurassic (Oxfordian).

The missing halite explains, among many other diverse phenomena, the well known metamorphic-grade discontinuity (at the weld) in the Northern Range, and also in Paria Peninsula, separating (A) the Güinimita-Laventille-Lopinot-Toco post-rift suite, showing incipient metamorphism only (shales locally converted to slate and phyllite; limestones locally recrystallized, impeding dating due to alteration of fossils), from (B) metamorphic older rocks (Maracas, Maraval, *etc.*), showing prehnite- to greenschist metamorphism (including Sans Souci rift volcanics), with shales entirely converted to phyllite and schist.

These three "new" concepts, namely early northern orogeny (in fact a 1970s idea), "late" Caribbean Arc arrival (1980s), and massive halite dissolution, will profoundly

affect oil and gas exploration in Trinidad, changing interpretations and predictions of subsidence history, paleogeography, structure (halite décollement), traps (thrusting; dissolution collapse structures), heat flow (high thermal conductivity of halite), seismicity, previously unsuspected evaporitic source rocks, seals, *etc.* For example, rejecting the popular Gulf of Paria pullapart model, in favor of halite-dissolution subsidence, negates both a supposed 11 Ma change in Caribbean relative motion, from ESE to ENE, and major dextral slip (10s km) on mythical east-west master faults in Trinidad that have never been found and that cause severe dextral palinspastic disruption, with vital implications for oil exploration.

This report presents the Campanian to Recent evolution of Trinidad in detail, meticulously presenting the diverse evidence for deep-halite dissolution (from outcrops, wells and seismic profiles) and for long-lived northern provenance (based on southward fining, olistolith compositions, cannibalization and heavy minerals). The report is a painstaking synthesis of the literature, with the added benefit of the the author's 15 years of experience in the region, conducting outcrop and subsurface studies throughout Trinidad and Venezuela. Several enigmatic stratigraphic units are discussed in particular detail and demystified (*e.g.* Sans Souci, Toco, "Cherrycake", Soldado, San Fernando, Plaisance), as are the supposed El Pilar and Arima Faults. The report integrates and interprets a vast amount of published data, enhanced by outcrop observations by the author. Products include 14 new and original tectonogeographic maps (Maastrichtian through Quaternary) and five tables of data (olistolith compositions, heavy minerals, evaporite occurrences by formation, Trinidad-Venezuela halite-dissolution basins, and analagous basins worldwide). Aside from these benefits, the report can be used as a computer-searchable encyclopedia and literature source of Trinidad-Venezuela basins and formations. With onshore and onshore bid rounds scheduled in Trinidad for 2005-2006, plus the recently demonstrated continued potential for giant oilfield discoveries (*e.g.* Angostura, discovered 1999), no exploration company interested in this prolific petroleum province can afford to be without this report.

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