3.0 REGIONAL GEOLOGY

The epicentral zone of the January 12 Haiti earthquake extends roughly from the Port-au-Prince alluvial valley in the south central part of the country, eastward to the vicinity of Petite Goave along the north coast of the Haitian southern peninsula. Section 2.0 of this report, Seismological Aspects, describes the seismology and earthquake mechanics, and presents a figure showing the epicentral zone of strong shaking (Figure 2.3).

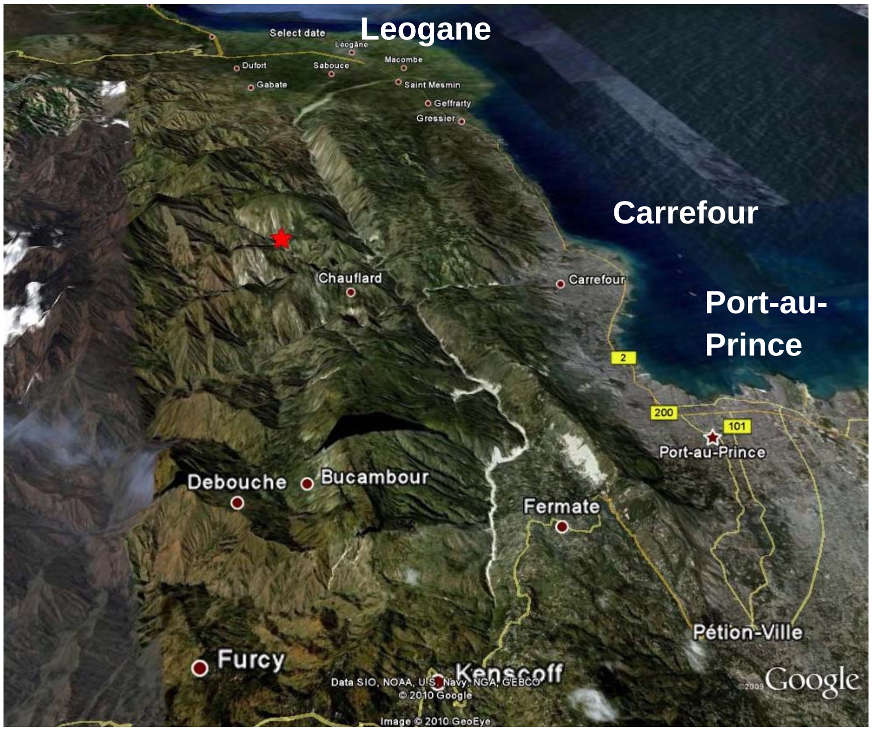
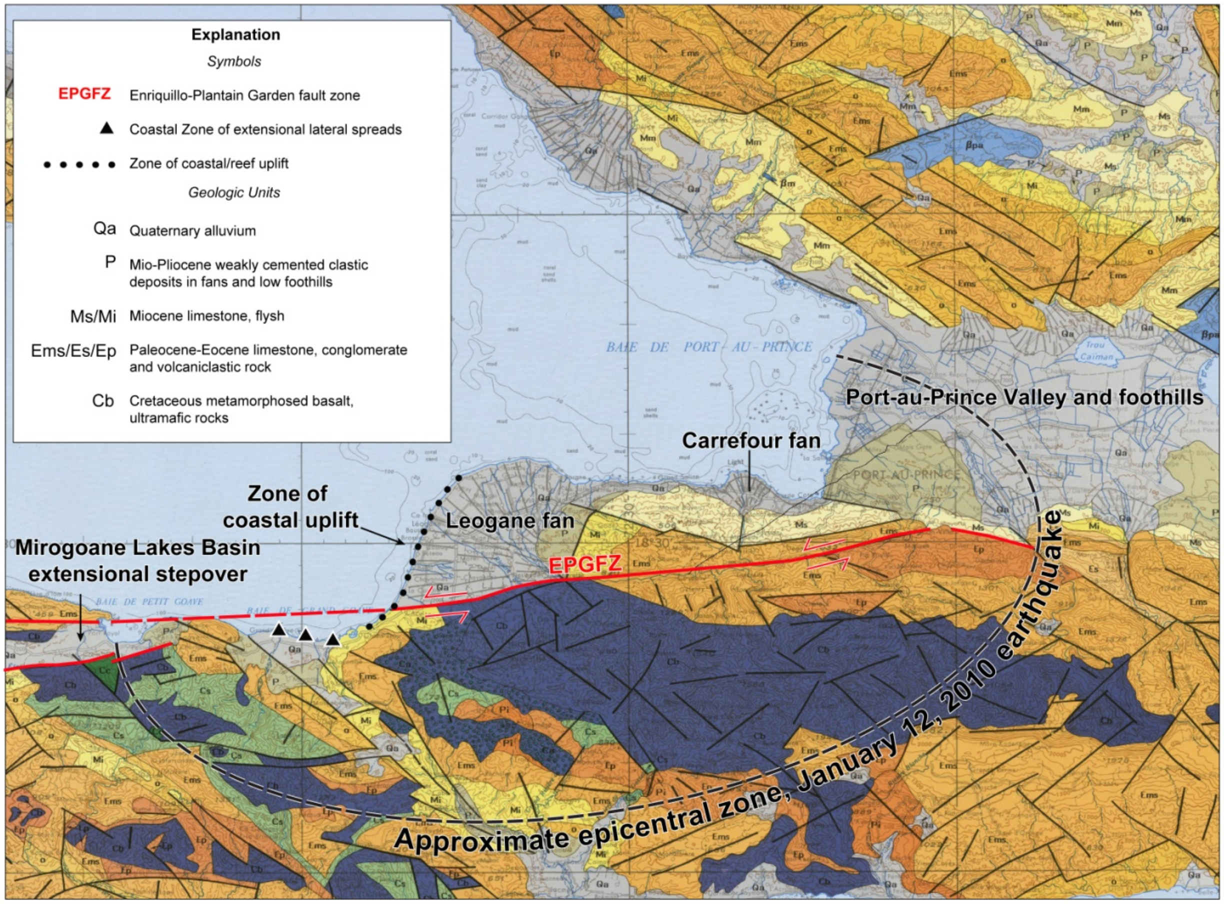


Figure 3.1. View west of Enriquillo Plantain Garden fault zone. Fault extends west-southwest from Pétion-ville along the prominent linear valley of the Frorse and Momance rivers at center of picture. Epicenter of 12 January M 7.0 earthquake shown by red star. The rupture extended west from the epicenter, away from Port-au-Prince.

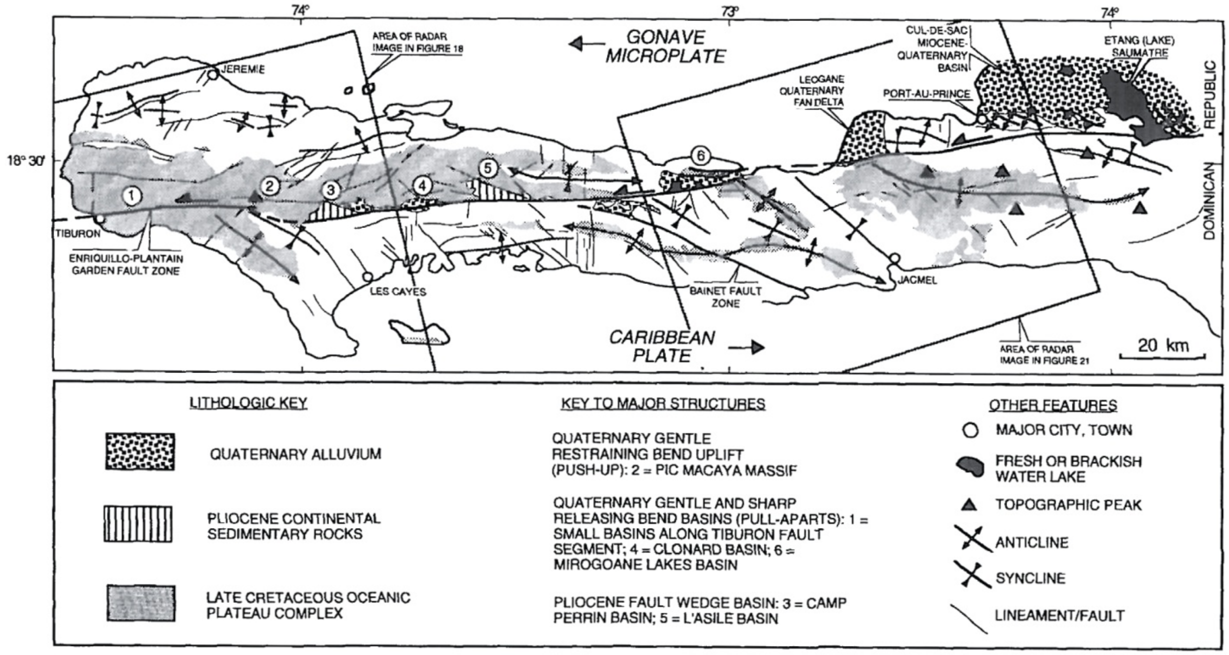
The earthquake occurred on the Enriquillo-Plaintain Garden fault zone (EPGFZ), a major tectonic element with a long history of deformation and slip. The fault traces roughly west-east along the north portion of the southern Haiti peninsula (Figure 3.1), and has exerted a substantial topographic/geomorphic influence since the Tertiary. Quaternary displacement along the fault has formed a classic strike slip fault geomorphology including linear valleys and bounding uplifted mountains, shutter ridges, sag ponds, and elliptical basins at extensional stopovers and bends along the fault trace. Some stream reaches, such as within the deep valley of the Frorse and Momance rivers that follows the EPGFZ trace, are apparently the result of both stream capture by recent displacements along the fault and preferred incision along sheared and locally weaker rocks along the fault zone (Figure 3.1). Additional discussion of the relationship between topographic features and the EPGFZ, and Quaternary geomorphic expression, are discussed in Section 4.0 of this report. Surprisingly, no evidence of surface fault rupture has been found by the GEER team or other field teams. These investigations have included visits to multiple reaches of the fault in the epicentral zone that have clear Quaternary-active geomorphic expression, and roadways/tracks that cross perpendicular or obliquely across the entire well-expressed fault zone.

The earthquake-affected region is a physiographically diverse area that has undergone a complex geologic history of intrusion, tectonism, erosion, and sedimentation. The topography within the study area is relatively rugged, with steep mountain ranges and hillfronts, deeply incised streams and narrow intermountain stream valleys, and broad coastal delta fans and valleys. Figure 3.2 is a geologic map of the earthquake epicentral area, based on original mapping by C.E.R.C.G. IMAGEO (Lambert, Gaudin, and Cohen, 1987). The map shows the central mountainous core of the southern peninsula to be locally underlain by metamorphosed Cretaceous basalt/mafic volcanic basement, and Cretaceous-Eocene limestone, conglomerate, and clastic sedimentary rocks. An east-west trending band of Miocene and Mio-Pliocene sedimentary rock (including flysch, siltstone, shale, sandstone) occurs along the coast and southern margin of the Port-au-Prince alluvial valley. Contacts between the Miocene and Mio-Pliocene units are commonly faulted, and small folds and possible thrust faults have deformed the Mio-Pliocene bedrock in response to a regional northeast-southwest compression, oblique to the trend of the strike-slip motion along the EPGFZ (Figure 3.3).



Modified from country-wide map by C.E.R.C.G. IMAGEO (Lambert, Gaudin, and Cohen, 1987).

Figure 3.2 Geologic map of January 12, 2010 Haiti earthquake epicentral area.



Note:
Tectonic map of the southern peninsula of Haiti (modified from Mann, 1983, and Vila et al., 1985). Numbers are keyed to major strike-slip-related structures listed on the map key. Boxes indicate locations of radar images interpreted in Figs. 18 and 21.

Figure 3.3. Regional structural geologic map. (Mann et al 1995)

Quaternary deposits in the earthquake epicentral zone include Holocene to late Pleistocene fluvial alluvium (channel, terrace, floodplain overbank deposits) deposited in the Port-au-Prince valley and interior incised river valleys, alluvial fan and colluvial wedge deposits along the margins of larger valleys, coastal delta fan complexes where larger streams (e.g., Momance and Frorse Rivers) discharge into the sea along the coast, localized organic sediments within marshes and swamps, and beach sands along protected portions of the coast. The central area of Port-au-Prince which was devasted by the earthquake spans from the relatively level floor of a large alluvial valley, southward onto low hills underlain by Mio-Pliocene deposits. Portions of the city are presumably underlain by thick sequences of Holocene to Pleistocene alluvium in a broad downwarped basin, but zones of high damage extend onto the Mio-Pliocene bedrock. The cities of Leogane (Figure 3.1, which experienced a high percentage of structurally collapsed buildings and extensive shaking damage) and Carrefour (Figure 3.1) are located on large delta fans, and underlain by a thick sequence of Holocene to Pleistocene alluvium.

The distribution of most dense or severe building damage from the earthquake appears to be at least in part correlative with geologic conditions (see Section 5.0 Damage Patterns). Amplified shaking likely occurred as a result of thick alluvial soils in the north-central and coastal region of Port-au-Prince, Carrefour, and Leogane. However, large zones of extensive and dense damage occurred in the southern portion of Port-au-Prince that extends onto the hills underlain by Mio-Pliocene, weakly-cemented deposits. Although these deposits are quite stiff and not generally perceived as representing a significant amplification hazard (e.g., Building code Vs30-based soil classification) other mechanisms of amplification may have been at work, such as topographic amplification, distributed slip/deformation along folds and blind faults, seismic wave focusing along geologic structures (folds and blind thrust faults), or basin margin effects. These effects may have contributed to higher levels of shaking or adverse frequency content in these materials. The correlation between geologic conditions and damage is discussed in Section 5.0 of this report. Filled ground in port areas of Port-au-Prince and Carrefour experienced classic liquefaction, lateral spread, and settlement damage. Port liquefaction and effects are discussed in Section 6.0 Port Facilities and Coastal Infrastructure.

Older Quaternary (Pleistocene) deposits include elevated sand and gravel fluvial terraces along major streams, older (inactive) portions of delta fans, and elevated coastal marine terraces. Some of the larger, older (late Pleistocene) alluvial fan complexes occur at the mouths of drainages along the south and north margins of the Port-au-Prince alluvial valley, and North Coast between L-acul and Gran Goave. Urban expansion south of Port-au-Prince and Carrefour extends onto the Mio-Pliocene bedrock hills and older alluvial fans.

The sediment carried by the active river systems is dominated by sand and gravel within braided channel systems in intermountain valleys and the mouths of canyons, and a distally-fining sequence of fine sand, silt, and clay at the distal ends of delta fans, coastal lowlands/marshes, and interior areas of larger alluvial valleys. Delta fans and alluvial valleys show evidence of relatively rapid sedimentation and considerable migration of active drainages through the Quaternary. As a result, distinct active and older sediment “lobes” or terraces can be differentiated based on elevation, degree of erosional modification, and soil development. Most of the large lateral spreads that occurred during the earthquake developed within artificial fill along the coast (e.g., Port-au-Prince and Carrefour ports), or at the distal noses of delta fans that are prograding into the sea between Leogane and Gran Goave. These failures are discussed in Sections 6.0 and 7.0 of this report.

Many of the road failures observed along the coast west of Carrefour occur where the road crosses marshy ground and the distal ends of small alluvial valleys. Settlement and localized creep/slumping of sediments underlying the road bed appears to be responsible for many of the road failures, rather than lateral spread failure, as cracking typically was confined to the road beds and fill, and does not extend through natural soils shoreward of the roadways. Localized liquefaction of loose, saturated sediments in these areas may have contributed to the road failures, but was not the major factor, as discussed in Section 8.0 of this report.

Numerous landslides and rockfalls occurred within the Mio-Pliocene and older limestone bedrock in steep slopes and roadcuts within the epicentral zone. In some cases these failures appear to have been restricted to colluvial soil and fractured/dilated rock within a weathered zone that extends about 1 to 3 m deep into the slopes. However, some deeper-seated slumps and debris avalanche/slide failures occurred in less-weathered, deeper bedrock in steep mountainous slopes. These failures appear in part to be influenced or controlled by bedrock joints or weak zones. Developments on steep slopes in places appear to have been impacted by slope raveling or foundation sliding/slumping, but appear to have been primarily damaged by possible topographically-induced amplified shaking or structural/design dictated by development on steep slopes (e.g., tall, slender columns on downhill sides of buildings constructed on steep slopes). These issues are discussed further in Section 9.0 of this report.

References

P. Mann, F.W. Taylor, R.L. Edwards, T.-L. Ku (1995) “Actively evolving microplate formation by oblique collision and sideways motion along strike-slip faults: An example from the northeastern Caribbean plate margin,” Tectonophysics, 246, p. 1-69.