Exploring Belize and its Barrier Reef: Formation, Ecosystem, Culture, and Human Influence on the Reef

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Abstract

The Mesoamerican Reef is the largest reef system in the Western Hemisphere. The origin and evolution of the Belize Barrier reef in the southern portion of this system is strongly controlled by local tectonics along the boundary between the North American Plate and the Caribbean Plate. Along this boundary, a northeast trending left-lateral strike slip fault causes extensional normal faulting along the eastern coast of Belize and extends northeast into the Caribbean Sea, forming a deep trench known as the Cayman Trough. This structural setting created topographic control, which localized reef growth, producing all major reef types (fringing, barrier and isolated platforms). Belize contains particularly high biodiversity for the region, with about 65 coral species and over 300 fish species, compared with just over 70 coral species and about 520 fish species in the entire Caribbean. Belize's reef system has been a vital source of food and protection from storm systems for the local population throughout history, and in recent times has provided economic stability through international tourism. However, human interaction, including siltation and agricultural runoff, along with natural threats such as climate change and hurricanes, pose extreme threats to the stability of the reef's sensitive ecosystem.

Purpose and Location

Belize is a multicultural nation with one of the only existing structurally controlled reef systems in the world. This system is separated from the mainland by a shallow lagoon and stretches ~250 km across the eastern border of Belize. During the Spring of 2009, geology students participated in a geologic field excursion to Belize in order to construct a cross section across the Central American arc system. The group began at the volcanic arc along the southern border of Guatemala and led across the left-lateral Montagua fault zone, continued northeast into the backarc and across the passive margin of Belize to the Belize Barrier reef (figure 1). This project focused on the modern and ancient geomorphology of the carbonate dominated region. Students explored the country's geology, ecology, and culture.

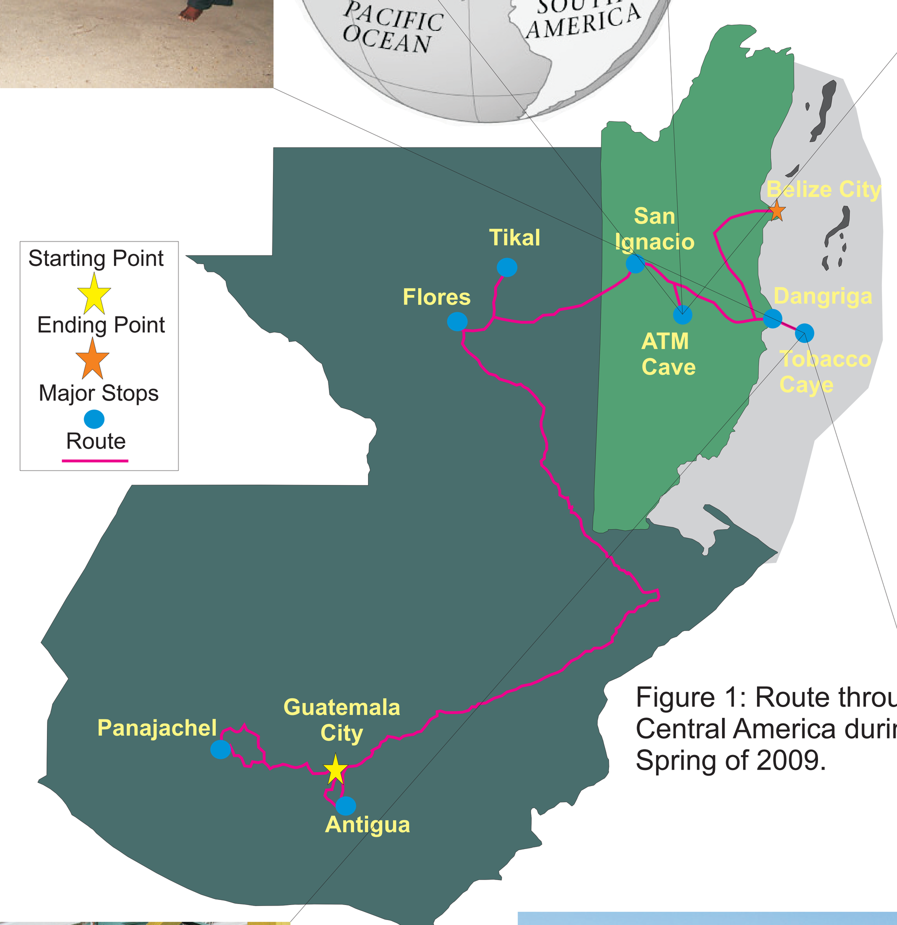


Figure 1: Route through Central America during the Spring of 2009.

Geologic Setting

Geologic Regions

The mainland of Belize is dominated by two geologic regions. The Paleozoic core to the south, known as the Maya Mountains, is composed of Silurian to Devonian granites which are overlain by Carboniferous and Middle Permian sedimentary, meta-sedimentary, and volcanic rocks. These overlying rocks were then deformed by a granitic intrusive event during the Triassic (Mazzullo, 2006) (figure 2). The northern region is composed of undeformed Jurassic siliciclastic rocks and Cretaceous to upper Tertiary carbonates (Mazzullo, 2006).The left-lateral Montagua fault zone in Guatemala to the south (figure 3) continues into the ocean as the Cayman Trough spreading center (750 km east off the coast of Belize) (Gischler and Hudson, 2003).

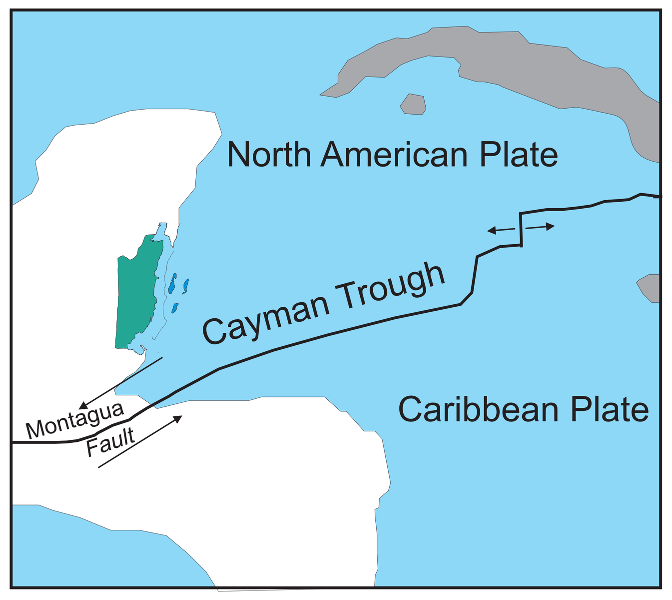


Figure3: Tectonic map of the Caribbean region showing the orientation of the Belize Barrier Reef on the North American Plate, separated from the Caribbean Plate by the Montagua Fault. Modified from Mazzullo, 2006.

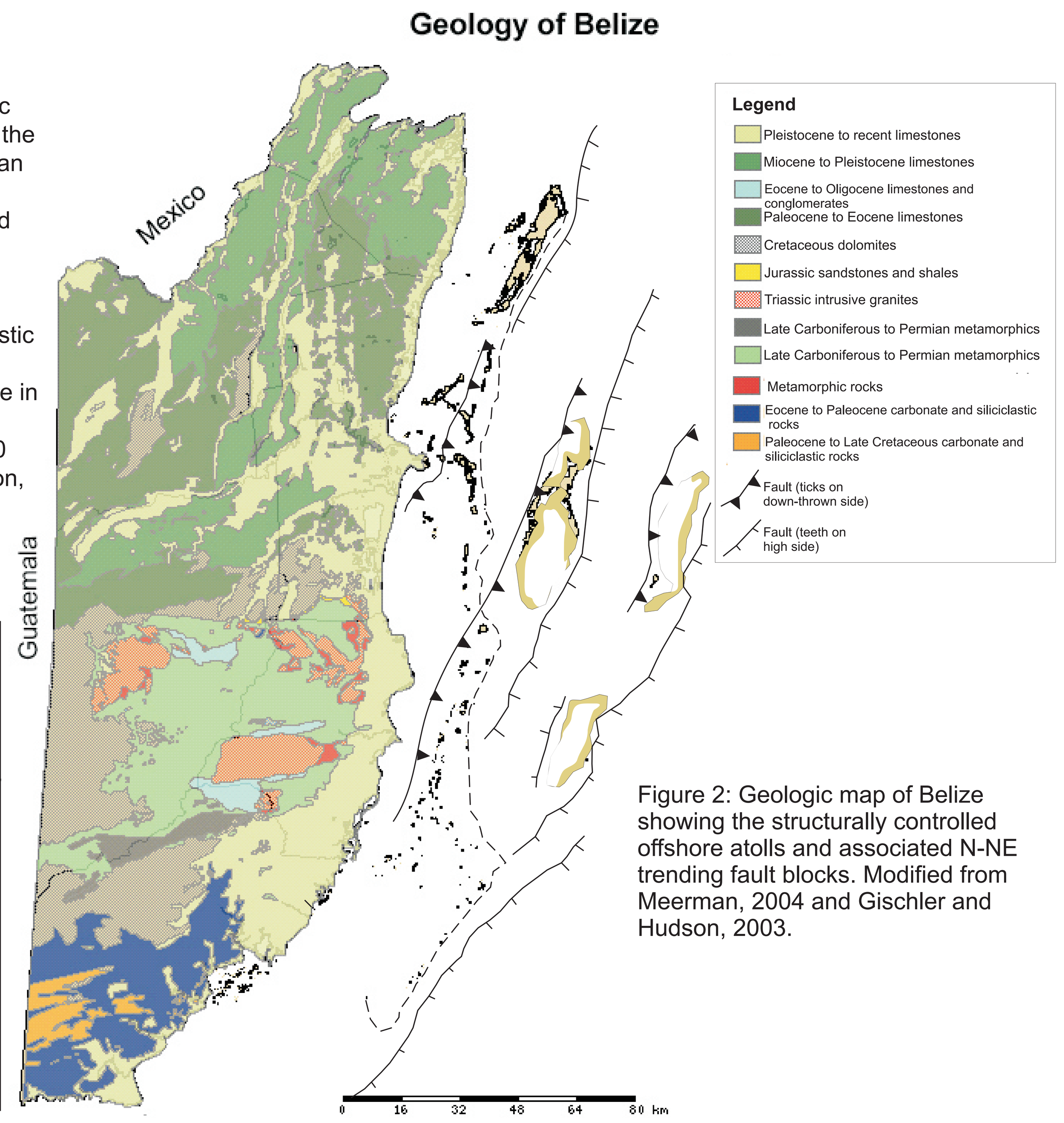
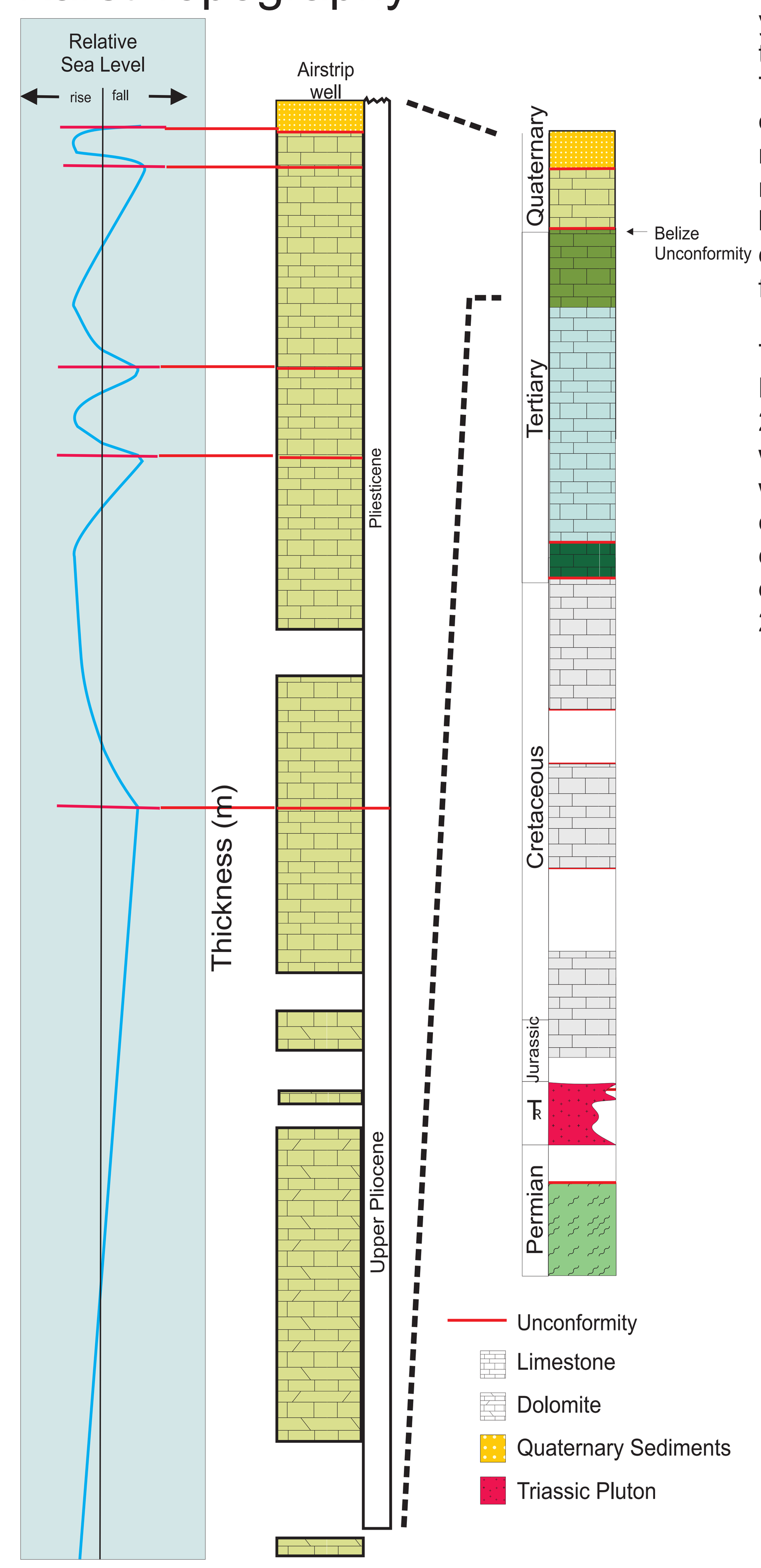


Figure 2: Geologic map of Belize showing the structurally controlled offshore atolls and associated N-NE trending fault blocks. Modified from Meerman, 2004 and Gischler and Hudson, 2003.

Structural Control

The seaward edges of the carbonate platforms within Belize are fault-bounded (Mazzullo, 2006) (figure 2), including three parallel N-NE trending fault blocks located to the east off the mainland (Gischler and Hudson, 2003). The N-NE fault blocks were initiated by tectonism during the Late Triassic and continued into the Cenozoic as the Caribbean Plate moved eastward along the Montagua Fault zone (Mazzullo, 2006). Uplift along these fault blocks has created the major structural features that govern reef growth (Mazzullo, 2006). Associated topographic highs as well as karstification processes have been the site for Pleistocene and modern reef formation (Gischler and Hudson, 2003). Belize has been relatively tectonically quiescent since the Oligocene (Mazzullo, 2006).

Karst Topography



The interface between the Pleistocene (1.8 Ma to 10,000 years ago) facies and the Holocene (10,000 years ago to the present) facies is an irregular unconformity (figure 4). This unconformity displays significant differences in elevation relative to the modern day sea level, generally ranging from 1 meter above the modern day sea level in the north to greater than 25 meters below the modern day sea level to the south (Gischler and Hudson, 2003). The difference in elevation is a result of subsidence along the fault blocks and karstification.

There is more karstification present in the southern parts of Belize, probably due to orogenic effects (Gischler et al, 2000). The unconformities within Belize represent a time where low sea levels exposed the carbonate shelf to weathering and karstification processes (figure 5). The cyclic pattern of rising and falling sea levels directly correlate with the periods of karsting and carbonate deposition shown by unconformities (figure 4) (Mazzullo, 2006).

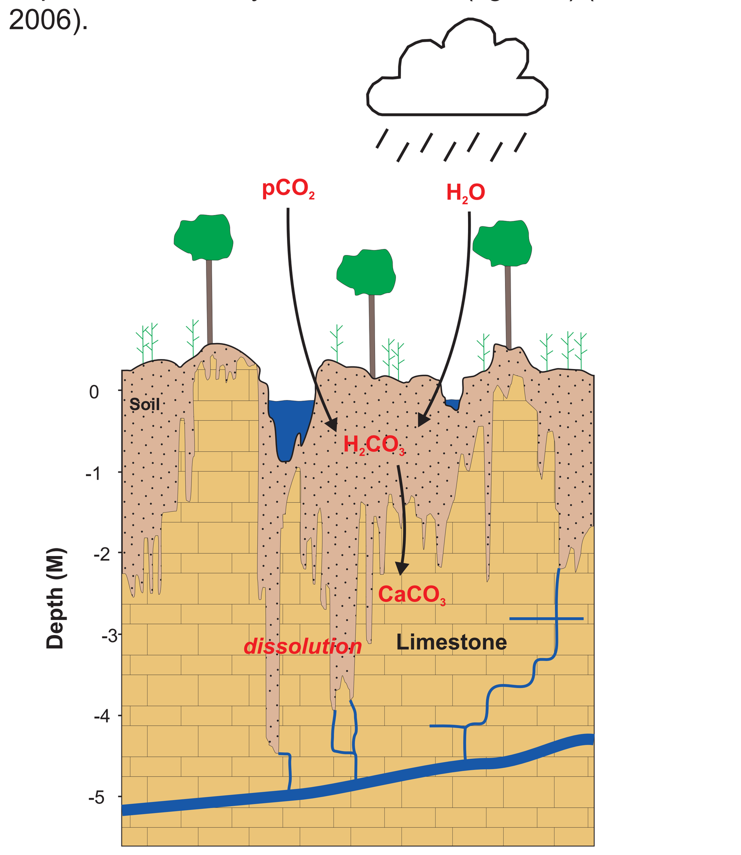


Figure 5: Karst topography formed by the dissolution of carbonate rocks. Modified from National Atlas: USGS, 2008.

Figure 4: Stratigraphic section of northern Belize from the Pennsylvanian to the present. Composed of dominantly carbonate rocks that are prone to karsting processes. Several unconformities are present throughout the depositional history of Belize, correlating well with karst formation at periods of low sea level stand. Colors correlate to figure A. Modified from Mazzullo, 2006.

Reef Biodiversity

The Belize Barrier Reef system is extremely biodiverse and has been important for industry and tourism in Belize. The reef shelters the main land, and the areas behind it, from the rough ocean waves, providing a safe habitat for life to thrive. The reef is home to 65 of the 70 known coral species and 300 of the 520 known fish species in the Caribbean as a whole (Wells, 2004). As it stands, an estimated 10% of the species within the Belize Barrier Reef have been discovered. It is also home to a large Manatee population, endangered sea turtle species, and salt water crocodiles.

Culture and Influence

Caves within the karsted lowlands of Belize have provided religious sites and sacrificial chambers for the Ancient Mayan civilization throughout the classical Mayan period and well into the post-classic period. The group visited the Actun Tunchil Muknal (ATM) cave (figures 6-8) which was used for religious ceremonies from 650-900 CE.

Present day coastal regions of Belize play a large role in the local economy through tourism (about 250,000 people per year (World Factbook, 2009)), shipping, and seafood exports. The population of Belize is estimated at 320,000 people, which is the lowest population density in Central America and one of the lowest in the world. Even with such a low population, the reef is heavily influenced by human activities (figures 9 and 10). It has been estimated that over 40 percent of the reef system has been damaged since 1998 (Wells, 2004).

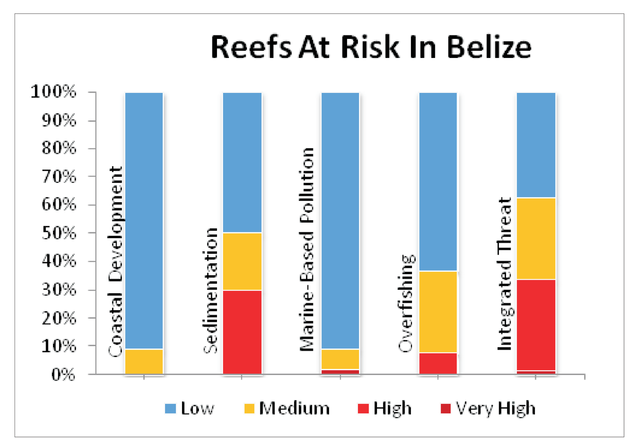
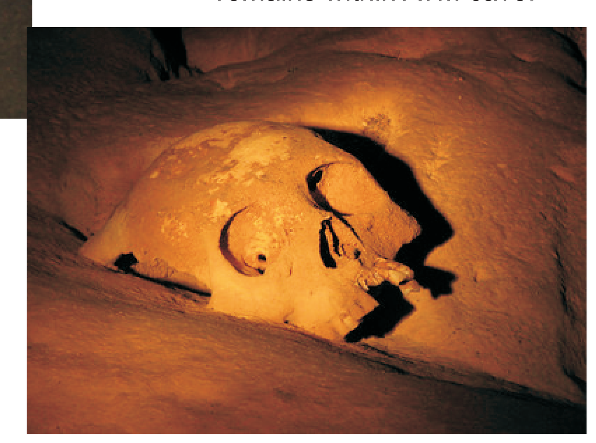


Figure 9: Human influences causing ecological shifts within the Belize Barrier Reef. An analysis done by the World Resource Institute (WRI) indicates that over 60% of Belize's reefs are threatened by human activity (Burke et al., 2005). Modified from Burke, 2005.

Figure 6: Cave formations display an image of a goddess within the ATM cave.

Figure 7: Clay pots are found throughout ATM cave.

Figure 8: Sacrificial skeletal remains within ATM cave.



Integrated Threat to the Reef System

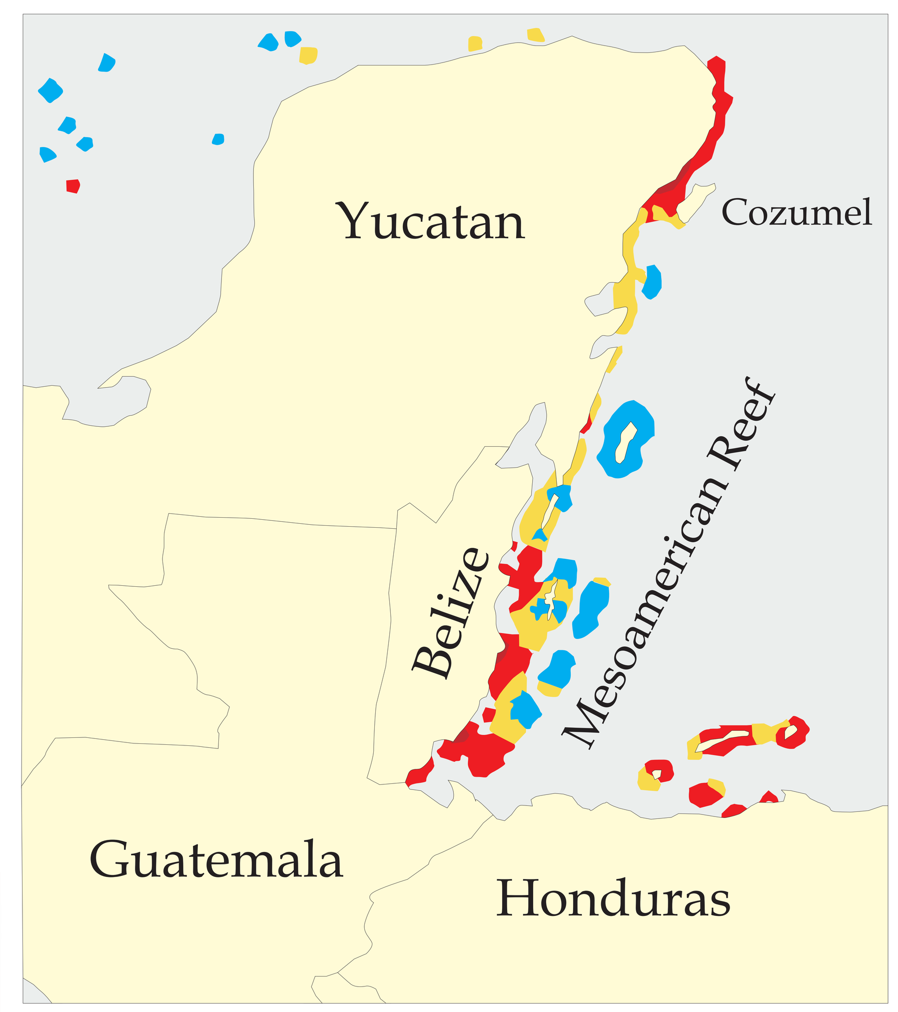


Figure10: WRI analysis indicates major human influences along the eastern coastline of Belize. See figure ? for color scale. Modified from Burke et al., 2005.

Importance

This geologic field excursion provided an unparalleled opportunity to study the cross-section of the modern arc processes of Guatemala and the unique structurally controlled backarc reef system of Belize. This excursion has been a perfect opportunity for understanding the unique geologic regions as well as gain crucial cultural experiences which cannot be found locally.

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