Structural Geology of Guam

BI201 Natural History of Guam
Class Presentation 16

- **Structural Geology**
  - Structural geology is the study of the deformation of the crust of the Earth
  - This deformation includes both processes and products
    - Products are usually termed **structures**
  - Structures may be **tectonic** (or *neotectonic*) or **nontectonic**

Types of Structures

- **Folds**
  - A fold is a bend in rock strata
  - The flexure may be
    - **synformal**
      - A synformal fold is a basin- or trough-shaped fold whose younger layers may be above or below older ones (e.g., a *syncline*) or
    - **antiformal**
      - An antiformal fold is an arch-shaped rock structure that, by definition, arches upward, usually with the oldest rocks in the core (e.g., an *anticline*)

Synform

Antiform

Fold Mountains

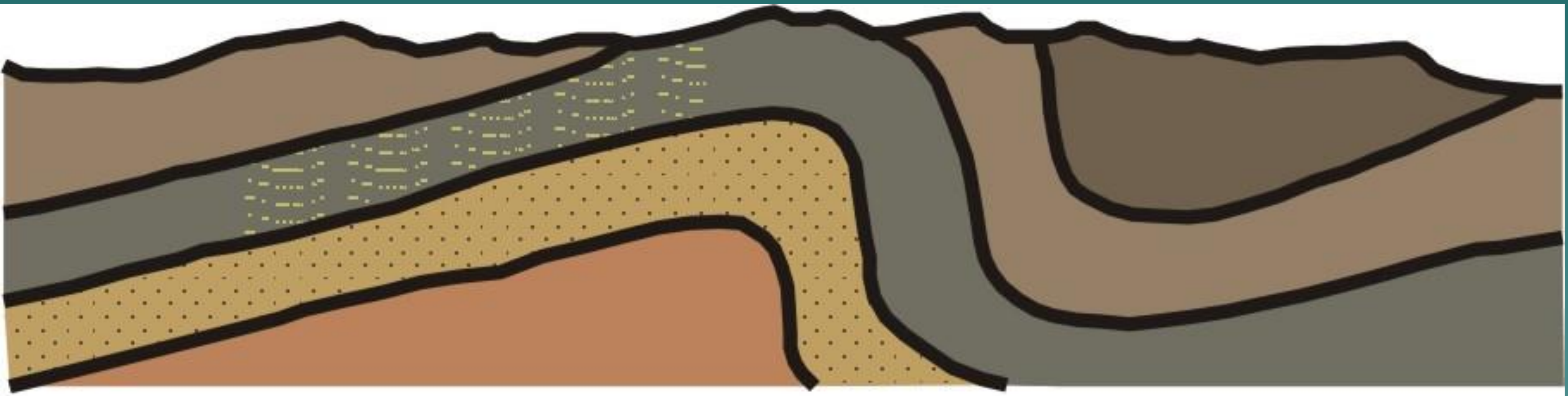
(Scale = meters to 10s of meters)

(Scale = 10s to 100s of kilometers)

(All side views)

- Folds may be caused by *compressive* forces or by *ductile* strain
- Folds may evolve into faults
- Folds are prominent structures in “fold mountains” (Himalayas, Andes, Alps, Urals, Atlas, Apennines, Appalachians, Carpathians, Rockies)
- Folds are uncommon in plateaus where gentle warping is the principal structure
- Folds are important as traps for hydrocarbons and ore minerals

- Folds are uncommon on Guam and throughout the Mariana Islands
  - Most folding in the Marianas occurs in the forearc or accretionary prism of the convergent plate boundary
- In Guam, folds occur in the volcanic tuffaceous rocks on the Agat-Umatac Road
  - The folding is asymmetric and has produced brittle, tensional structures called **joints**, as well as **drag folds**, small satellite folds on the major **limb** of the fold



Fold with drag fold

- Additional folds occur in cuts immediately north of the Cetti Bay overlook and in similar rocks on Mt. Alutom
  - These folds probably represent *synsedimentary slumping*, a form of non-tectonic folding that developed during the deposition of volcanic sediments in deep water on the steep slope of the volcanic cone

- **Joints**
  - A joint is a fracture or crack in bedrock, along which there has been little or no movement parallel to the plane of the fracture
    - The fracture may be caused by tensional forces or brittle failure
  - Joints often occur in well organized groups or sets

A high angle joint in the Facpi Volcanic Formation

- The orientation of joints is commonly related to a regional stress field
- Joints are crudely planar and their spatial orientation or **attitude** is described by **strike** and **dip** measurements
  - **Strike** is the compass direction of a horizontal line in the (joint) plane; it is the equivalent of azimuth
  - **Dip** is the acute angle between the (joint) plane and the horizon; it is perpendicular to strike

- Joints are key factors in the development of permeability of a rock body, and thus, its value as a reservoir for water (**aquifer**) or hydrocarbons (**trap**) or as a host for **mineral ores**
- Joints are common on Guam and throughout the Mariana Arc
  - Joints are pervasive in the limestone sections of northern and southeastern Guam, where they control the development of caves and sink holes

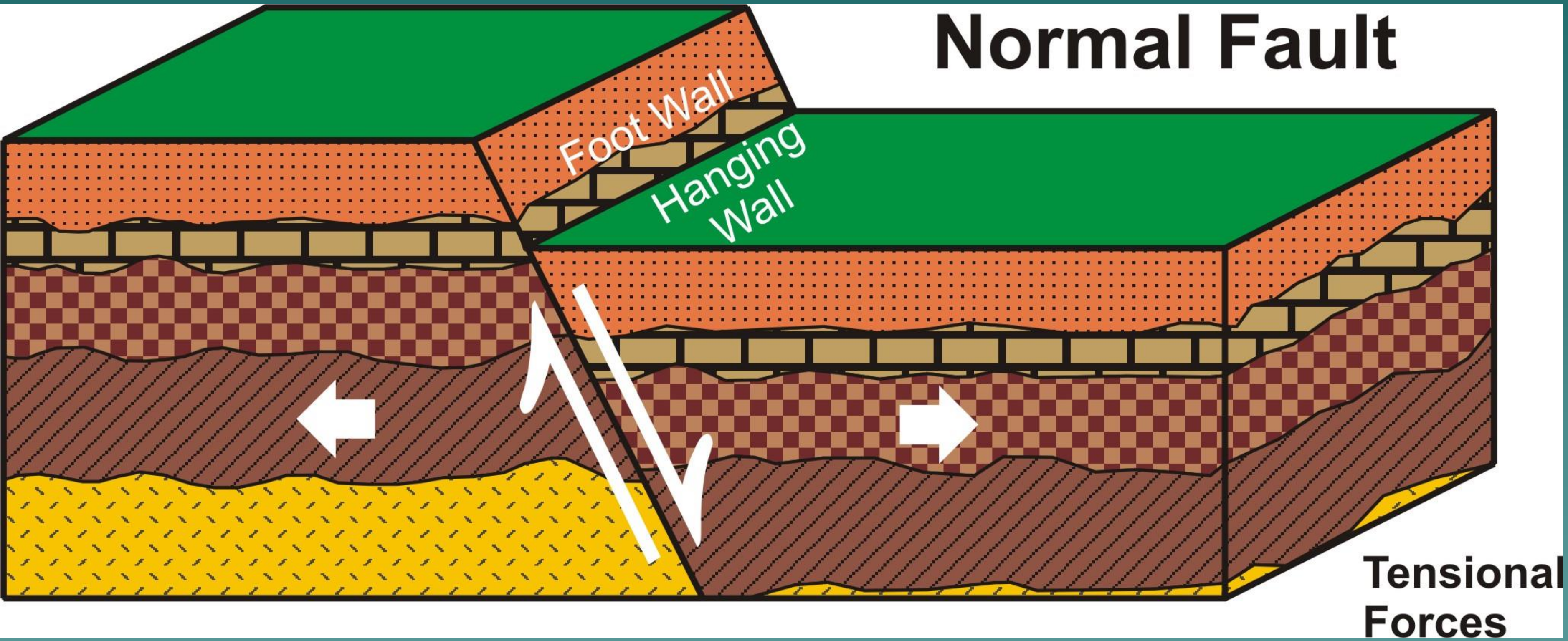
- Joints are important controls on the recharge, movement, and storage of groundwater in both the north and south
- Joints are important controls on drainage patterns (e.g., Bubulao, Lonfit Rivers).

Surface drainage in southern Guam is controlled by joints.

- Joints are responsible for many of the second- and third-order topographic features on Guam
- Joints are critical geological structures for the civil engineer to recognize when designing bridges, dams, etc. and siting buildings; however, they are usually overlooked in Environmental Impact Assessments (EIA) on Guam

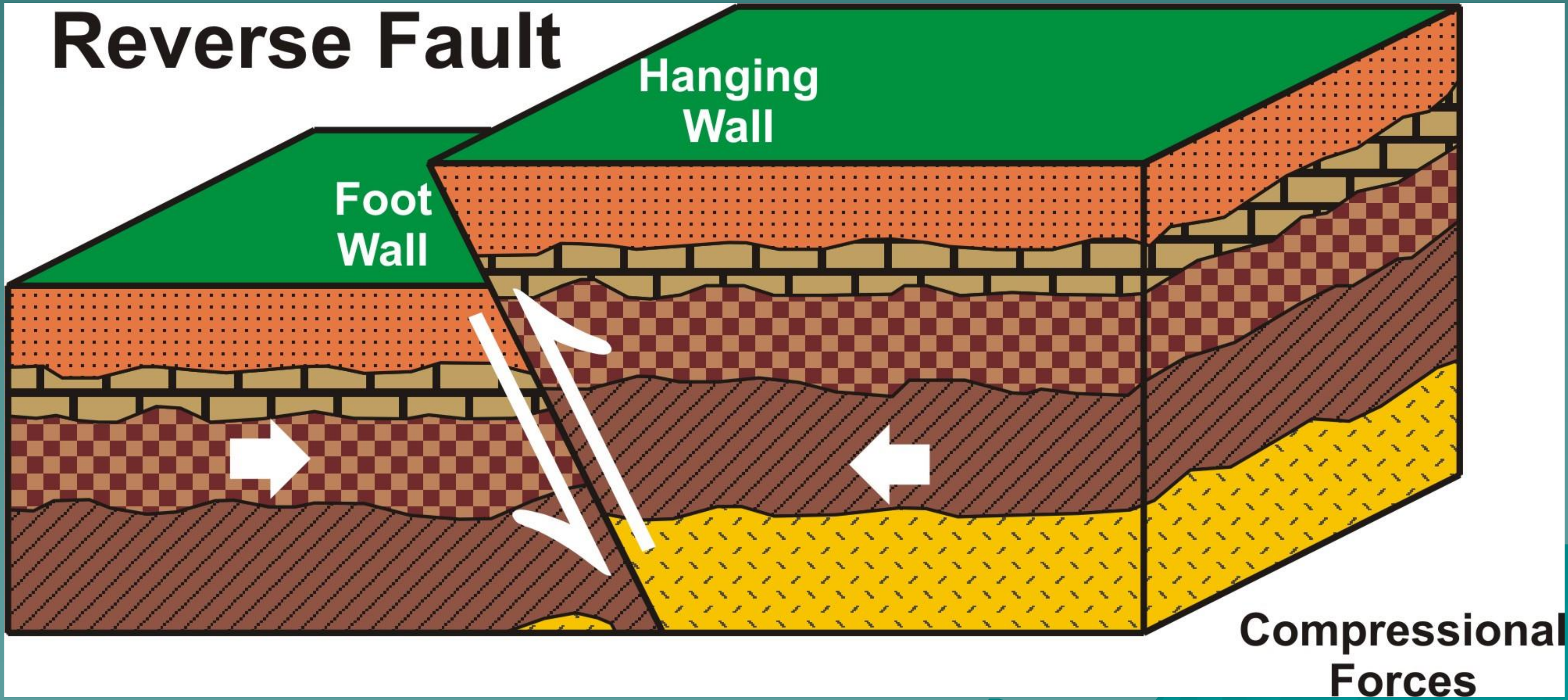
- **Faults**
  - Faults fractures (planes) in bedrock along which there has been movement
  - The plane is called the **fault plane**
  - The fault plane is rarely simple, and quite often it is a zone comprised of many faults, not all of which move the same direction or at the same time

- In the fault zone, rocks tend to be highly deformed and brecciated
- Faults are named according to the relative motion of the two crustal **blocks** (masses of rock) on either side of the fault plane:
  - **Dip-slip faults**
    - The relative displacement is parallel to the dip of the fault plane in a dip-slip fault
    - **normal** (or gravity) **fault**
      - A normal fault is a high-angle (> 50 °) fault in which displacement is downward

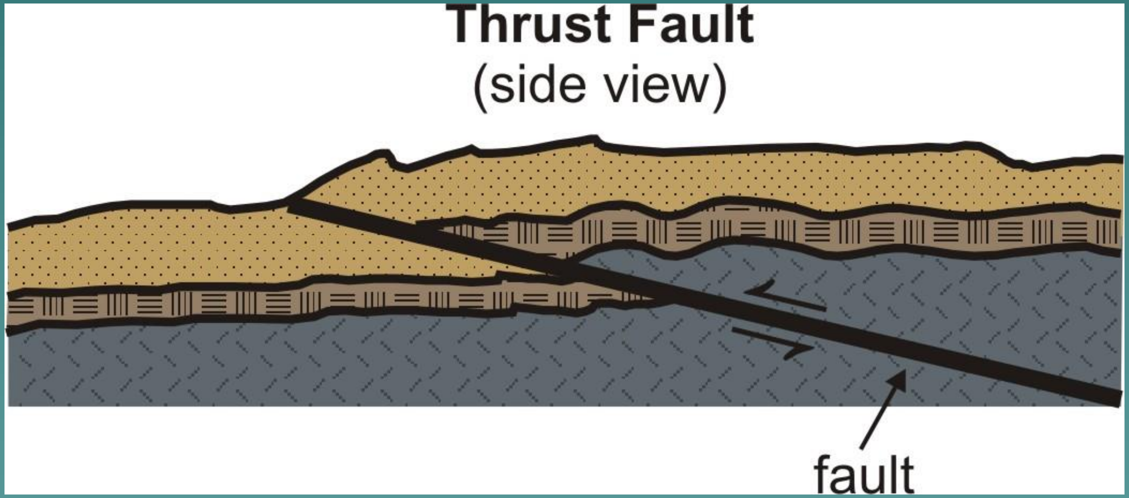

Normal Fault
Foot Wall
Hanging Wall
Tensional Forces

– **reverse fault**

- A reverse fault is a low-angle fault in which displacement is upwards

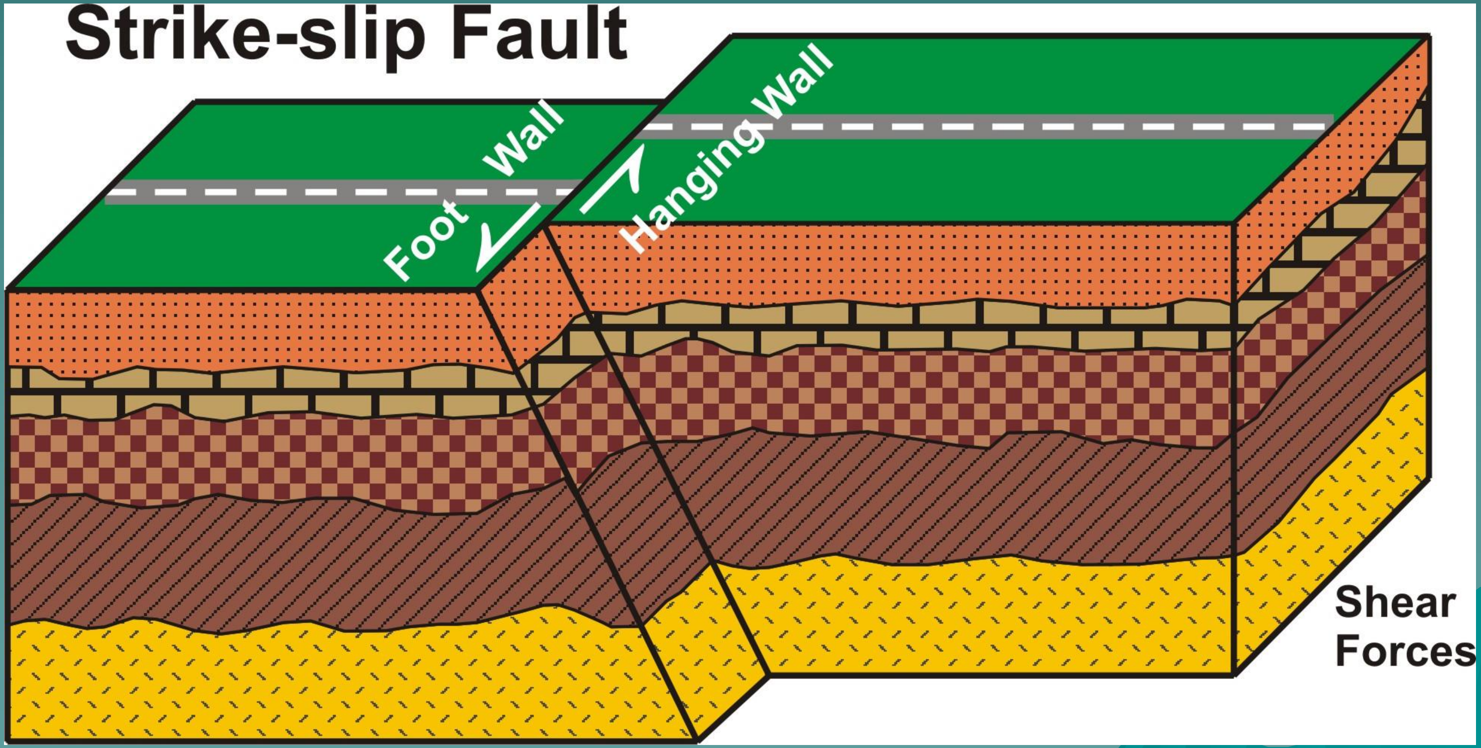


- Reverse faults with low dips are called **thrust faults**



– **strike-slip faults**

- In strike-slip faults, the relative displacement is lateral, i.e., horizontal



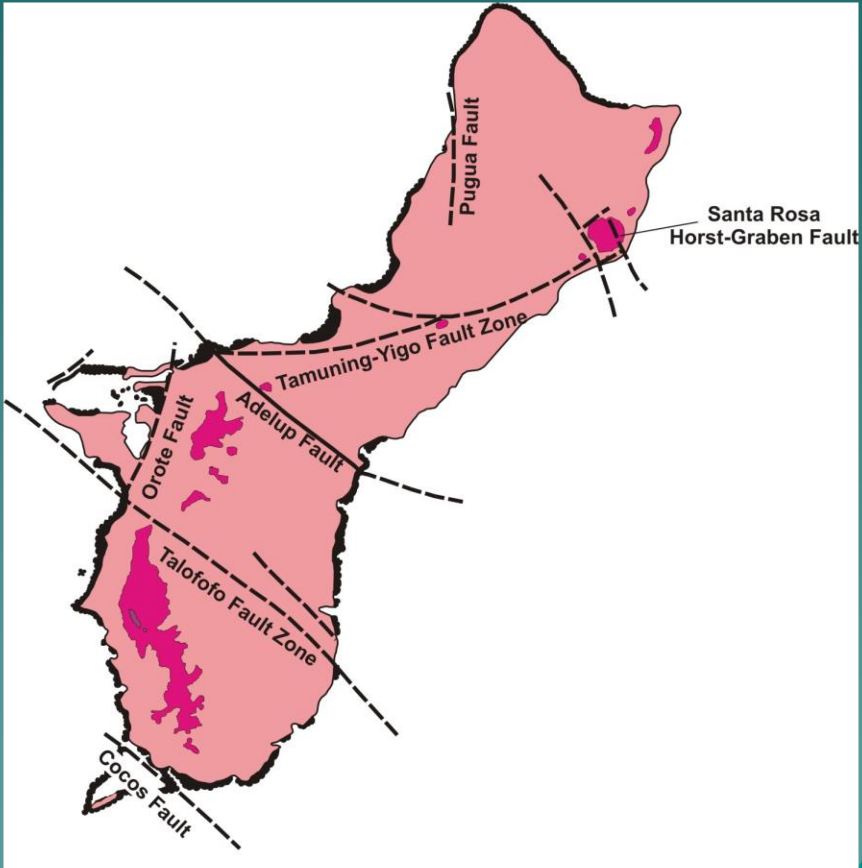
- Large strike-slip faults (especially those on the ocean floor normal to spreading centers or between tectonic plates) are called **transform faults**

- Faults produce many of the same side-effects as do joints, but much more so
  - They are the cause of **earthquakes** (sudden releases of strain energy tectonic blocks, causing surface rupture and perceptible surface vibrations) and a whole spectrum of secondary hazards related to quakes

- Faults are
  1) a major control on first order topography, drainage, and slope stability
  2) a significant factor in the occurrence and size of geologic resources, the formation of wetlands, and the configuration of coastlines
- Depending upon the rate of erosion, faults may or may not produce **scarps** (i.e., steep slopes or cliffs found at the margin of a flat or gently sloping area)

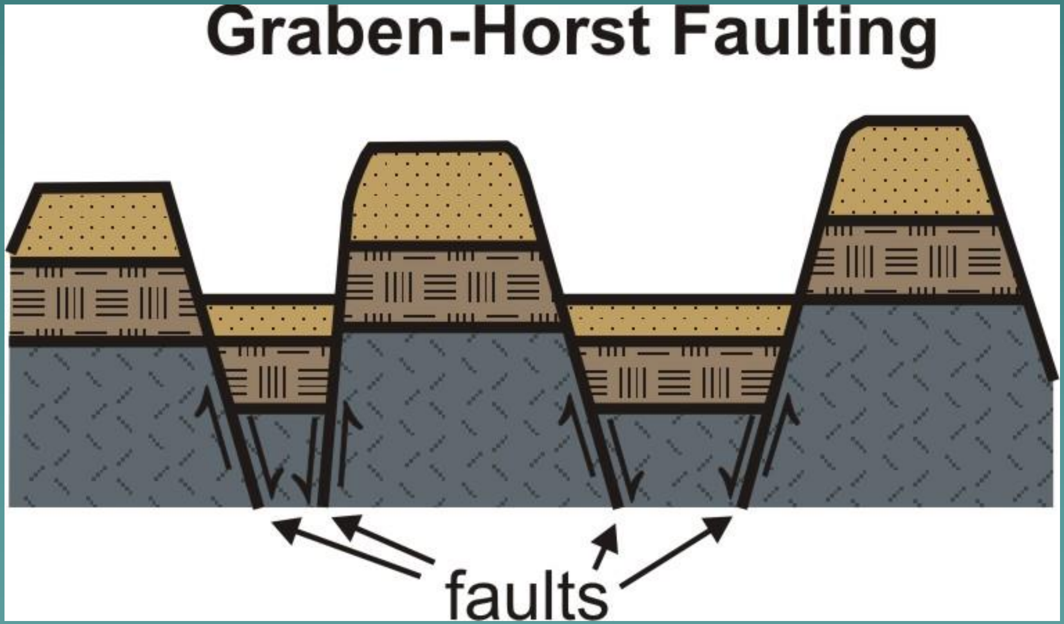
- Faults are common features on Guam and throughout the Mariana arc
  - Most, if not all, of the large faults on Guam are steeply dipping normal faults associated with vertical uplift of the arc

– Major faults on Guam are the
  - **Adelup Point-Pago Point Fault** (passing through the Governor's Mansion, Ordot Dump)
  - **Talofofo-Santa Rita Fault** (passing throughNaval Magazine)
  - **Yigo-Tamuning Fault** (beginning at Alupang Cove Condo)
  - **Orote Fault**
  - **Cocos Fault**



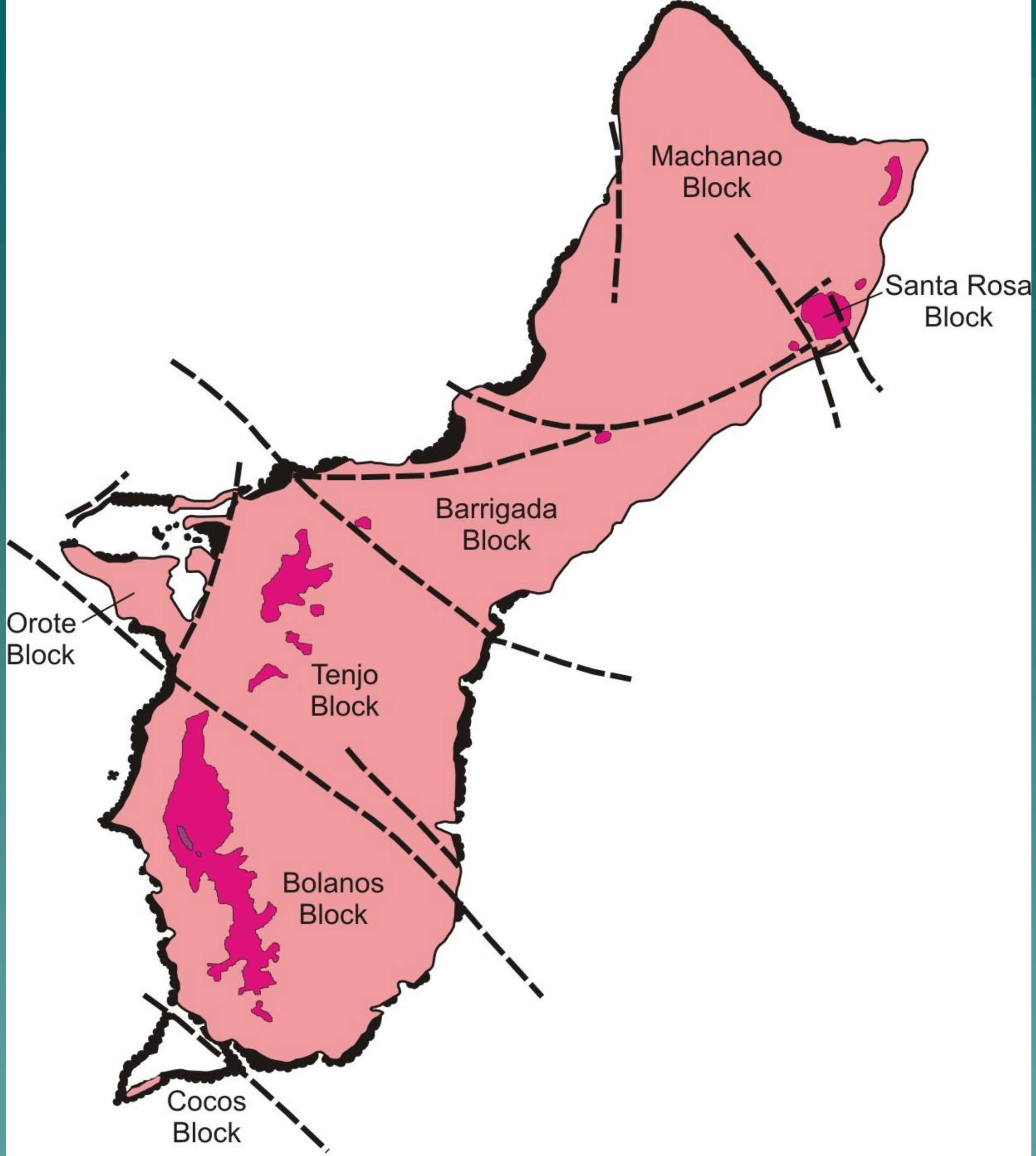
Major faults and fault zones of Guam.
[Modified from Tracey et al., 1964].

- Mt. Santa Rosa is a **horst-graben** structure
  - Horst-graben structures are by an up-raised block bounded by normal faults



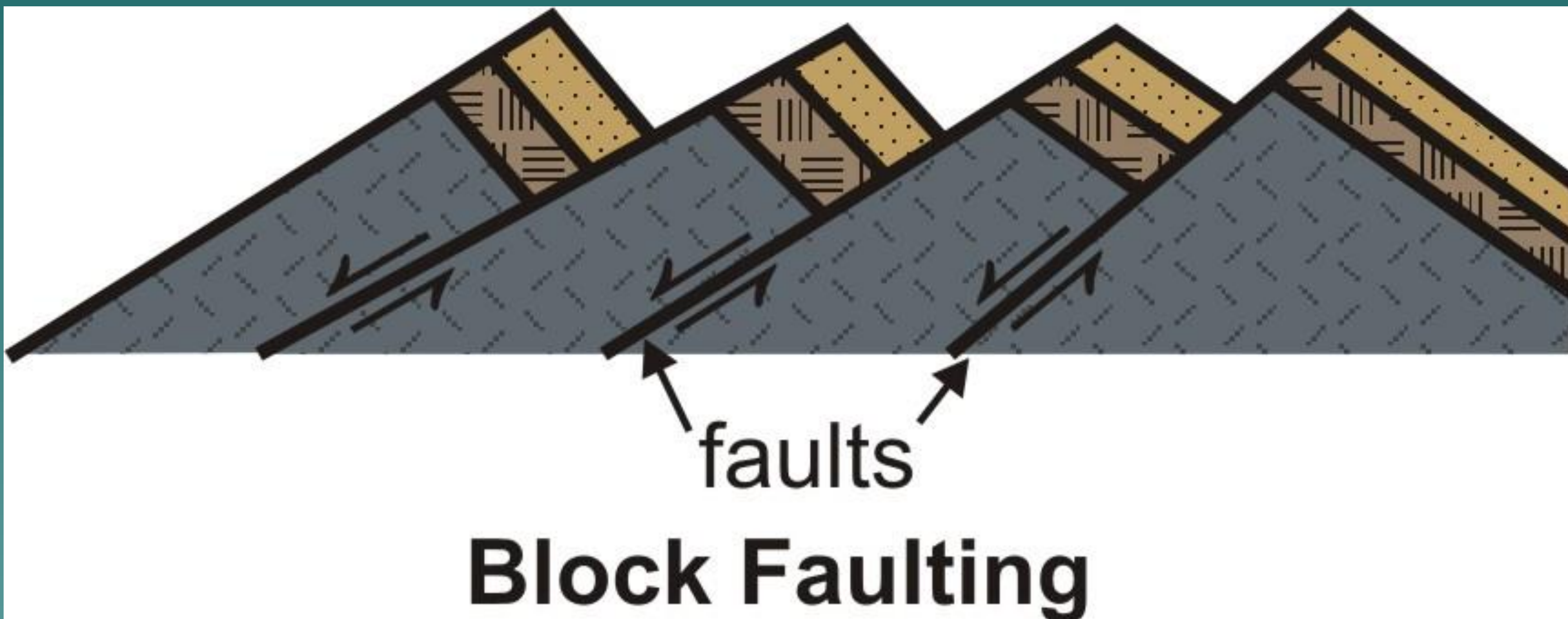
- There are literally hundreds of other faults, many unmapped, crisscrossing Guam
- The major faults divide Guam into three provinces:
  1) **Limestone plateau land** of northern Guam is bordered on the south by the Adelup fault zone
     - Agana Swamp covers the down-faulted area and was level with Sinajana and Maite before down-faulting
  2) **Eocene-Oligocene volcanic rock** of central Guam
  3) **Miocene volcanic rock** of southern Guam

- Each province can be further divided into subunits called blocks
  - The northern limestone plateau land is subdivided by the Tamuning-Yigo fault zone, hinging at Mt. Santa Rosa
    - The **Machanao Block** is north of the fault and the **Barrigada Block** is south



Major blocks of Guam, produced by the major fault zones. [Adapted from Tracey et al., 1964].

- The Eocene-Oligocene volcanic rock is subdivided by the Orote fault
  - The **Orote Block** is west of the fault and the **Tenjo Block** is east
  - The **Orote Fault** is an example of a block fault
    - The western tip of Orote Peninsula is tilted up, and the eastern area is tilted down
    - After faulting, the sea flooded the landward side, creating the inner harbor


faults
Block Faulting

- The Miocene volcanic rock is subdivided by the Cocos fault
  - The **Bolanos Block** is north and the **Cocos Block** is south
  - The Cocos Block almost disappeared beneath the sea and now supports Cocos Barrier Reef system

- Faults are responsible for
  a) The coastal configurations at Ritidian Point, Orote Point, Tarague, Haputo, Aga Point, and Campanaya Point
  b) The formation of Cocos barrier reef system
  c) The occurrence of "Double Reef‟
  d) The depth of the Talofofo Bay

e) The drainage patterns of the Ylig and Inarajan Rivers
f) The width of most of Guam's reef flats
g) Some of the slumping and alluvial fan development in southern Guam
h) In northern Guam, faults are a prime source of bedrock permeability, and they play an enormous role in directing recharge into the aquifer & thence to the reef

- The timing of the initiation and subsequent movement of the larger faults on Guam are clearly related to tectonic strain along the Mariana arc, e.g., great quake 8/93
- Many geological features may represent weaknesses in the underlying "basement" rocks and may have been more or less active since the island formed
- Others originated in the basement and do not extend into the younger limestones above and thus could be considered "extinct"

- Still others are obviously of more recent origin, cutting only younger limestones
- To the north, major faults dictate topographic divisions on Rota, Tinian and Saipan
- Major transform faults, especially north of Pagan, run perpendicular to the axis of backarc spreading that is coincident with the Mariana Trough, west of the Mariana Islands

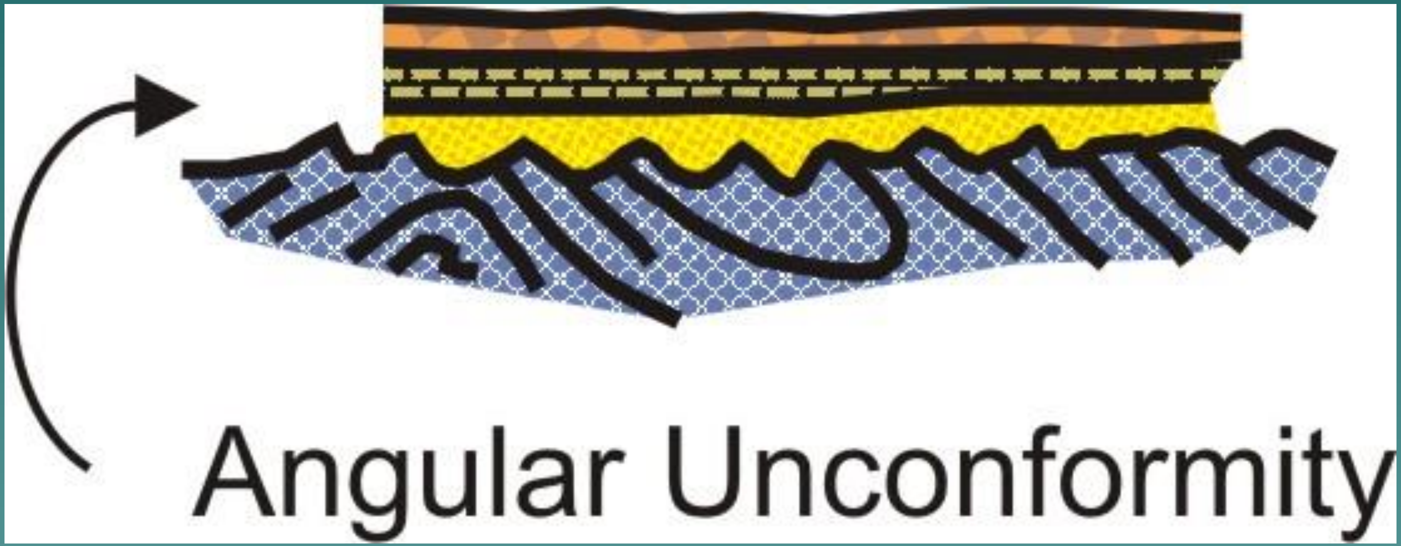
- **Unconformities**
  - **Unconformities** are erosional surfaces developed between geological formations
  - They indicate the interval of time between the deposits on top and below the surface
    - That period may be as short as a few tens of years (hiatus) or as long as 4 billion years

The Bolanos Pyroclastic Member of the Umatac Volcanic Formation rests unconformably upon the Schroeder Pyroclastic Member.

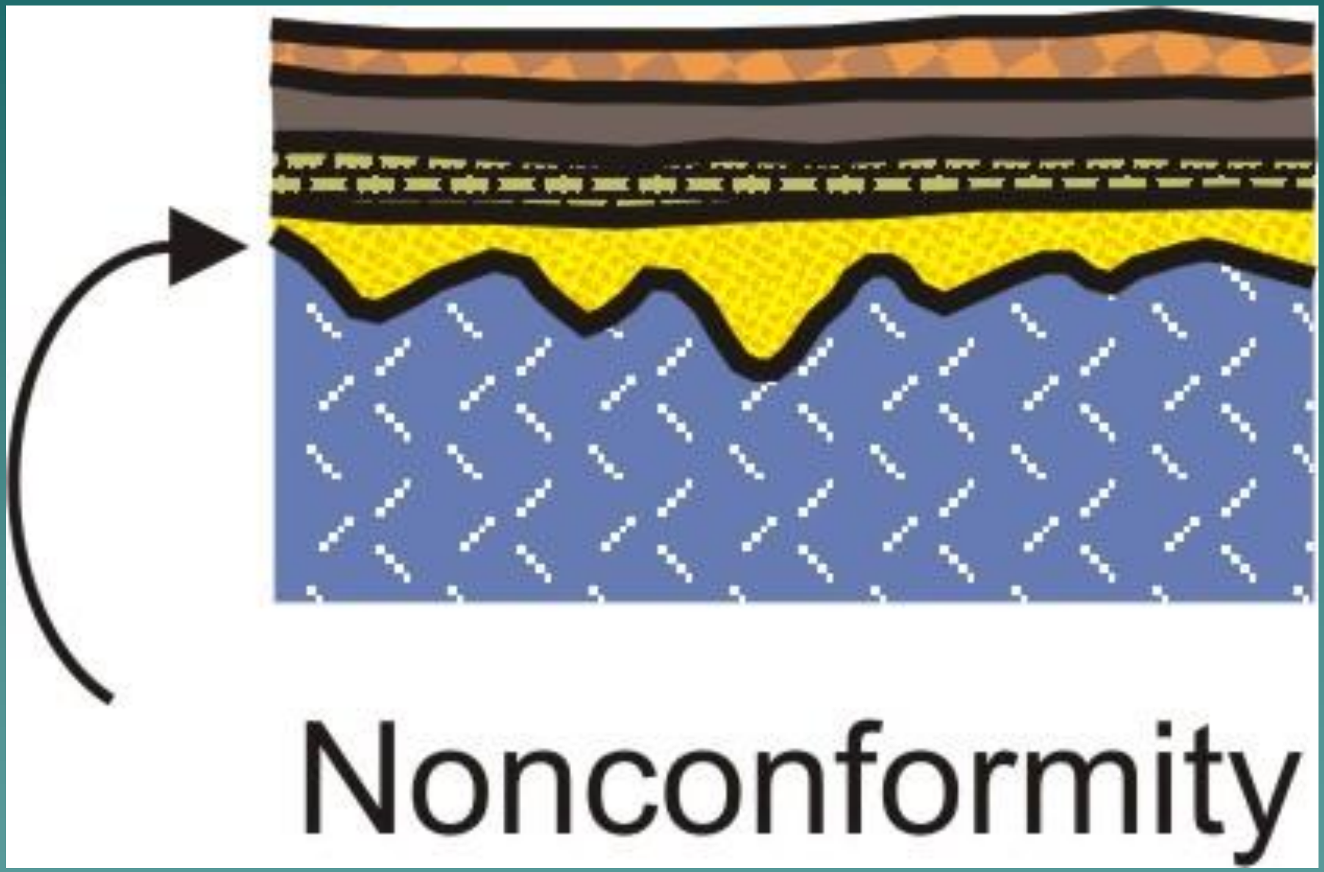
- It is often impossible to ascribe how much of the underlying formation has been eroded
- Unconformities have been the traditional mechanism for subdividing the Geologic Time Scale

- **Disconformities** (or *erosional unconformities*) separate horizontal layers above from horizontal layers below
  - On Guam, the Mariana Limestone (Pliocene) sometimes rests disconformably on the Barrigada Limestone (Miocene)

- **Angular unconformities** separate rock formations with different attitudes
  - This type of unconformity implies longer time interval elapses between upper and lower formations (i.e., the lower formation must be folded, uplifted, eroded, or submerged again under the sea, before younger formation is deposited)
  - On Guam, the Mariana Limestone is separated from the Janum Limestone (Upper-Middle Miocene) by an angular unconformity


Angular Unconformity

- **Nonconformities** separate overlying sedimentary rock from older igneous rocks below
  - On Guam, the Maemong Limestone (Upper Oligocene-Lower Miocene) lies nonconformably on the Facpi Formation (Upper Eocene) in the Geus River valley and on the Bolanos Formation (Lower Miocene) in the Talofofo River valley


Nonconformity