Geology & Groundwater
of Saipan

August 5, 2009

CNMI Division of Environmental Quality
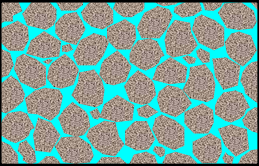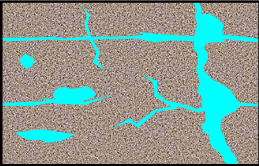

Geology & Groundwater

TOPICS:

- What is Groundwater?
- Saipan Geology
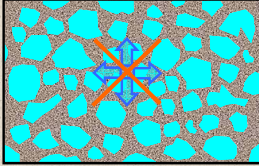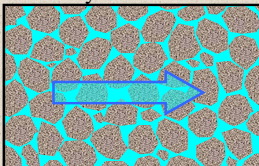- Where do you find groundwater?
- Wells
- Contamination

Groundwater:

- How can water exist in rock????
- Porosity:
- Primary porosity
  - Function of rock's primary structure (granular, crystalline, platey, etc.)
- Secondary porosity
  - Fractures
  - Solution channels
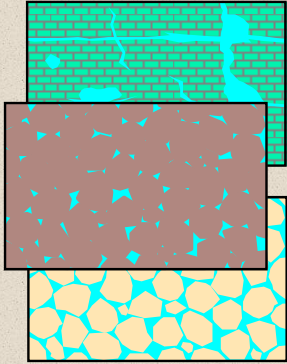 - Voids, caverns, vugs

Porosity = 40%

Porosity = 15%

Groundwater:

- How does water flow through rock????
- Permeability
- Porosity does not equal Permeability!!!
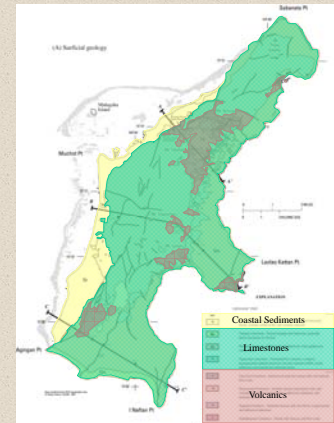- Permeability = "Connected porosity"

Permeability:

Dependent on the type of rock:

- Limestone
  - Very high permeability;
    - 'Thousands' ft/day
- Coastal sediments
  - Sands are permeable
- Volcanics
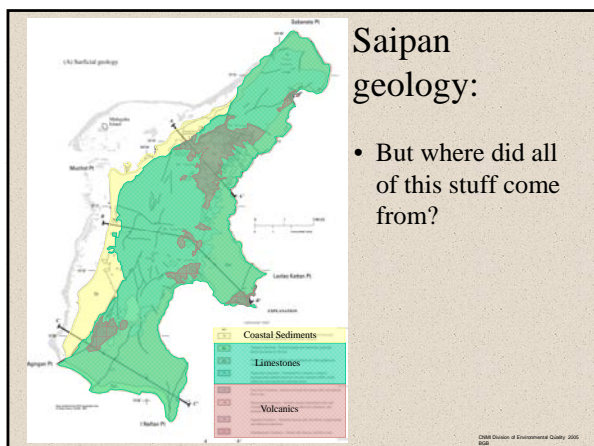 - Essentially not permeable: "impermeable"

Coastal Sediments

Limestones

Volcanics

Saipan geology:

- Limestones
- volcanics
- Coastal sediments

Saipan geology:

- But where did all of this stuff come from?
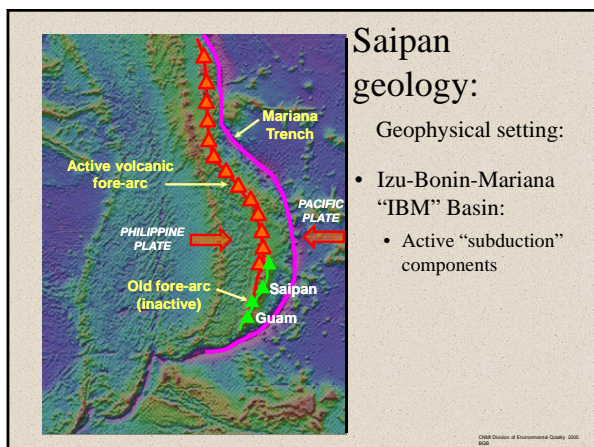
Coastal Sediments
Limestones
Volcanics

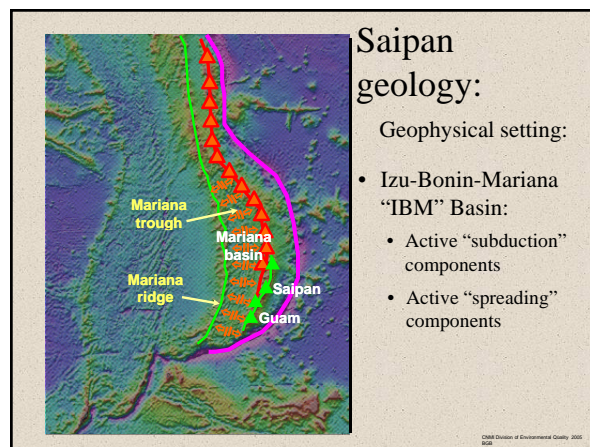## Saipan geology:

Geophysical setting:

- Izu-Bonin-Mariana "IBM" Basin:

Saipan
Guam

Saipan geology:

Geophysical setting:

- Izu-Bonin-Mariana "IBM" Basin:
  - Active "subduction" components

Mariana Trench
Active volcanic fore-arc
PACIFIC PLATE
PHILIPPINE PLATE
Old fore-arc (inactive)
Saipan
Guam

Saipan geology:

Geophysical setting:

- Izu-Bonin-Mariana "IBM" Basin:
  - Active "subduction" components
  - Active "spreading" components

Mariana trough
Mariana basin
Mariana ridge
Saipan
Guam
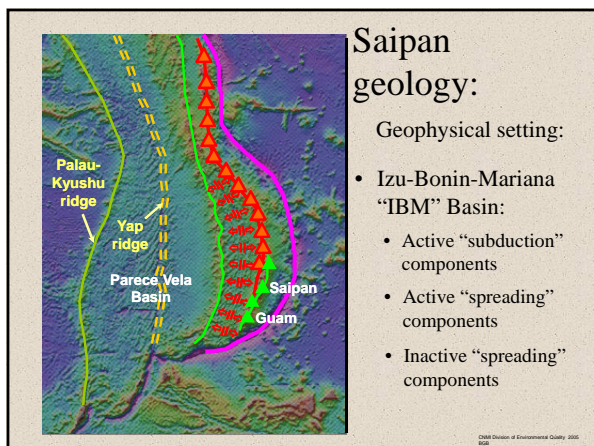
Saipan geology:

Geophysical setting:

- Izu-Bonin-Mariana "IBM" Basin:
  - Active "subduction" components
  - Active "spreading" components
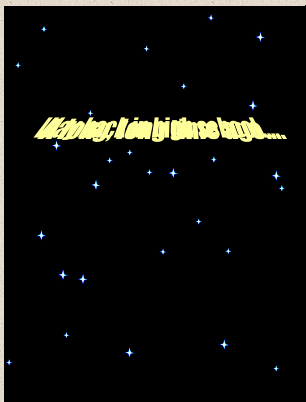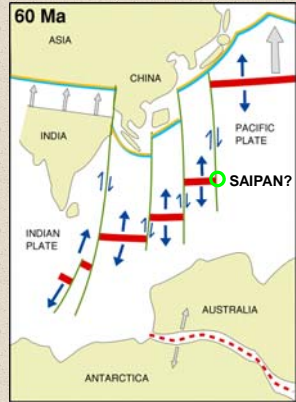 - Inactive "spreading" components

Palau-Kyushu ridge
Yap ridge
Parece Vela Basin
Saipan
Guam
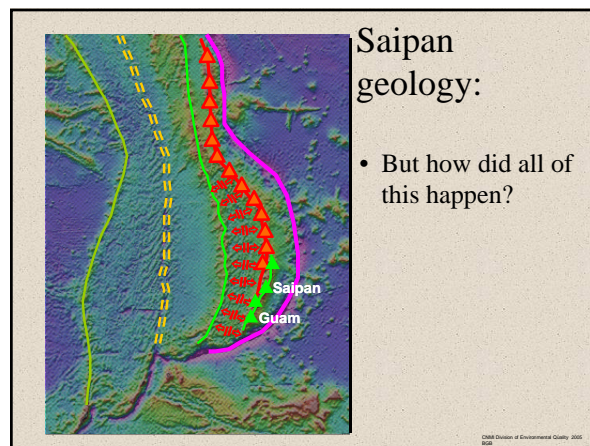
Saipan geology:

- But how did all of this happen?

Saipan
Guam

Slide 1

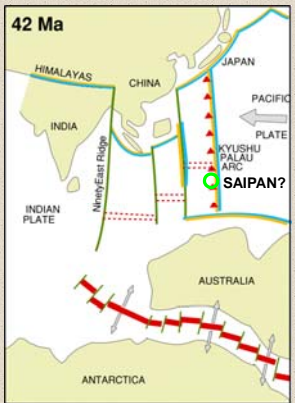# Saipan geology:

- Do you remember learning about…

Slide 2

Saipan geology:

- Plate Tectonics?
- 60 Million ago ("Ma"); there is no Saipan
- India and Australia are about to change everything
- Source: http://www.le.ac.uk/geology/art/gl209/lecture5/lecture5.html

Slide 3
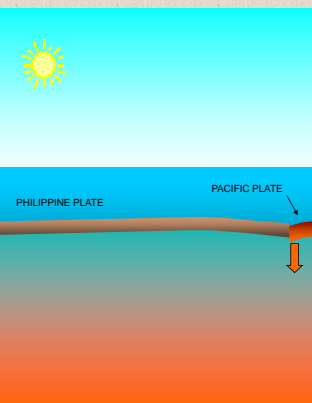
Saipan geology:

- Plate Tectonics:
- Pacific plate is forced to change direction; butts up against Philippine plate
- Still no Saipan
- Source: http://www.le.ac.uk/geology/art/gl209/lecture5/lecture5.html
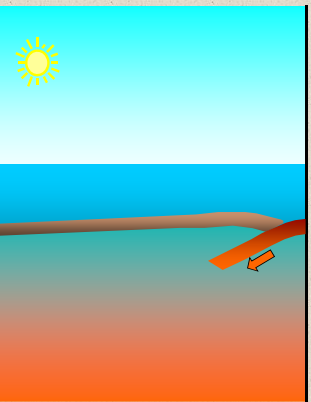
Slide 4

Saipan geology:

- Pacific plate begins begins to subside about 50 million years ago -"Ma"

Slide 5
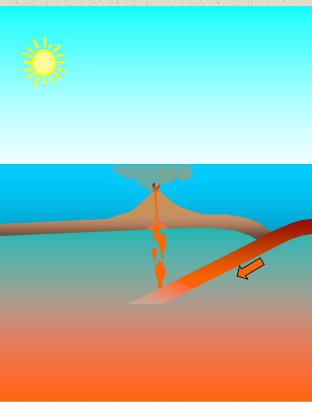
Saipan geology:

- Pacific plate begins "subduction" beneath Philippine plate ~43 Ma

Slide 6
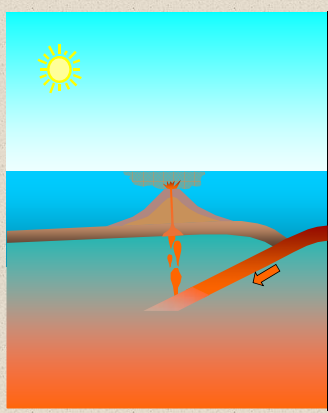
Saipan geology:

- Subducting plate heats and forms magma
- Saipan forms from initial volcanism: ~ 41 million years ago -"Ma"
- (Sankakuyama formation – 41 Ma)

Slide 1

Saipan geology:

- Volcanism continues up to about 30 Ma

- During this period, island breaks surface and erodes/subsides several times

Slide 2

Saipan geology:

- Volcanism continues up to about 30 Ma

- During this period, island breaks surface and erodes/subsides several times

- "Uplifting" begins

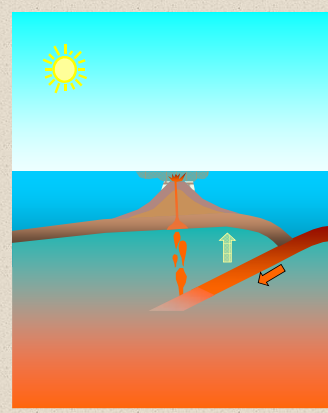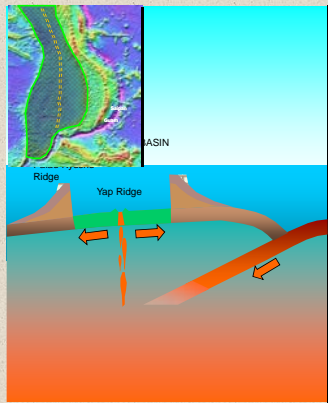- Marine sediments/reef building begins
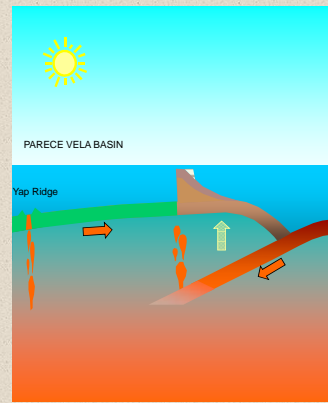
Slide 3

PARECE VELA BASIN

Ridge

Yap Ridge

Saipan geology:

- "Rifting" occurs at ~30 Mybp

- "Back-Arc Spreading" continues to ~15 Mybp; forming Parece Vela Basin

- Volcanism disrupted by rifting

Slide 4

PARECE VELA BASIN

Yap Ridge
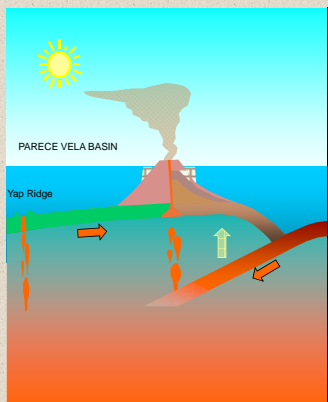
Saipan geology:

- "Rifting" occurs at ~30 Mybp

- "Back-Arc Spreading" continues to ~15 Mybp; forming Parece Vela Basin

- Volcanism disrupted by rifting

- "Uplifting" is enhanced by spreading

Slide 5

PARECE VELA BASIN

Yap Ridge
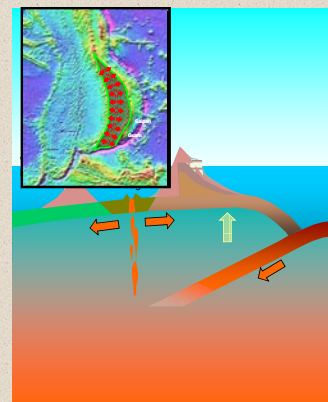
Saipan geology:

- Volcanism resumes along "Fore-Arc Axis" around 20 Ma:
  - "Magmatic maximum" ~ 13 Ma
  - Hagman, Deninsiyama, & Fina-Sisu formations
  - Complex layers of eroded volcanics, marine sediments

Slide 6

Saipan geology:

- Rifting occurs again ~ 10 Ma;
  - forming Mariana Basin; West Mariana Ridge

- Volcanism ceases permanently along "old fore-arc"

Slide 1

Saipan geology:

- Rifting occurs again ~ 10 Ma;
  - forming Mariana Basin; West Mariana Ridge
- Volcanism ceases permanently along "old fore-arc"
- Reefbuilding begins in earnest:
  - Tagpochau Limestone

(Diagram labels: MARIANA BASIN, West Mariana Ridge, Mariana Trough)

Slide 2

Saipan geology:

- Spreading/uplifting continues

(Diagram labels: MARIANA BASIN, Mariana Trough)

Slide 3

Saipan geology:

- Spreading/uplifting continues
- New Volcanic axis forms ~3-4 Ma
- Sea levels change

(Diagram labels: MARIANA BASIN, Mariana Trough, New volcanic axis)

Slide 4

Saipan geology:

- Major reef building continues:
  - Tagpochau Limestone
    - 10 Mya – 1.6 Mya
  - Mariana Limestone
    - 1.6 Mya -

(Diagram labels: MARIANA BASIN, Mariana Trough, New volcanic axis)

Slide 5

Saipan geology:

- Major reef building continues:
  - Tagpochau Limestone
    - 10 Mya – 1.6 Mya
  - Mariana Limestone
    - 1.6 Mya -
- Sea levels fluctuate (ice ages)
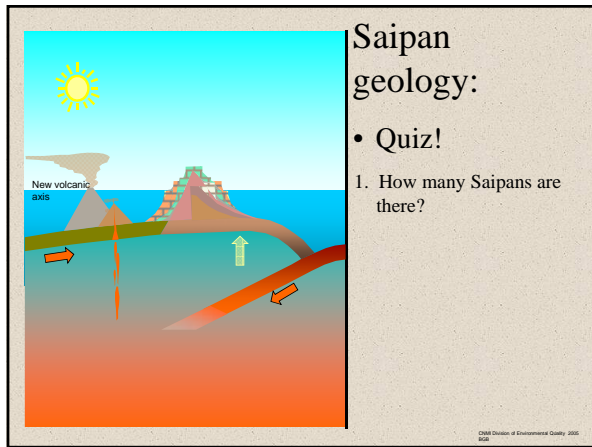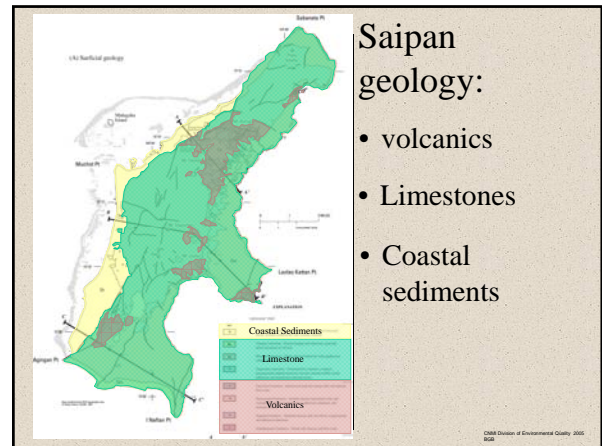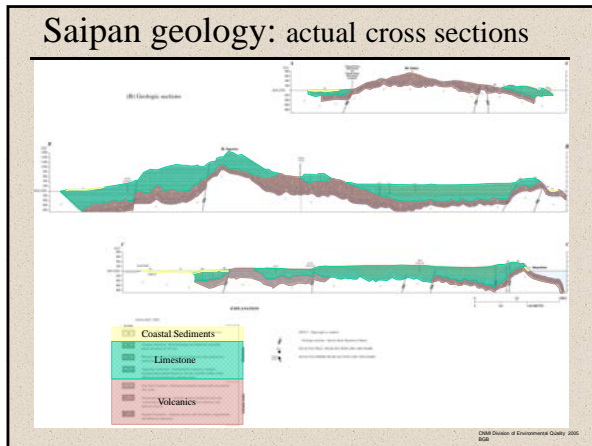- New volcanic axis grows; Northern Islands emerge
- Modern reefs; coastal sediments form

(Diagram label: New volcanic axis)

Slide 6

Saipan geology:

- Saipan takes on its present form
- Simplifying again:
  - Volcanics
  - Limestones
  - Coastal sediments

Slide 1

Saipan geology: actual cross sections

Coastal Sediments
Limestone
Volcanics

Slide 2

Saipan geology:

- volcanics
- Limestones
- Coastal sediments

Coastal Sediments
Limestone
Volcanics

Slide 3

New volcanic axis

Saipan geology:

- Quiz!

1. How many Saipans are there?

Slide 4

SAIPAN 2?   SAIPAN 3?   SAIPAN

Saipan geology:

- Quiz!

1. How many Saipans are there?

  A: three (sort of…)

Slide 5

Saipan geology:

- Quiz!

1. How many Saipans are there?

  A: three (sort of…)

2. Did Dinosaurs ever roam Saipan?

  A: No!

  Saipan formed 41 Ma; dinosaurs went extinct 24 M years before that (65 Ma)

Slide 6

MUNICIPAL WELL FIELDS ON SAIPAN

Aquifers:

- So where is the groundwater?

- Groundwater is everywhere

- But what about fresh water?

Aquifers:

- Fresh water "Lens"
- Fresh water is lighter than salt water
  - "Ghyben-Herzberg relationship"
- 1:40 ratio:
  For every 1 ft. "head" above sea level, 40 feet of fresh water below.

Basal Lens:

- Isn't that nice?
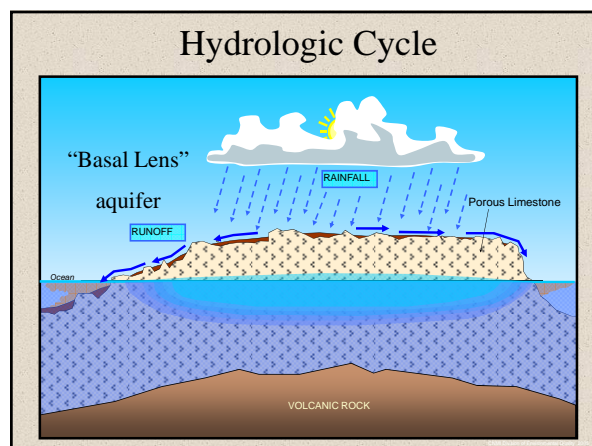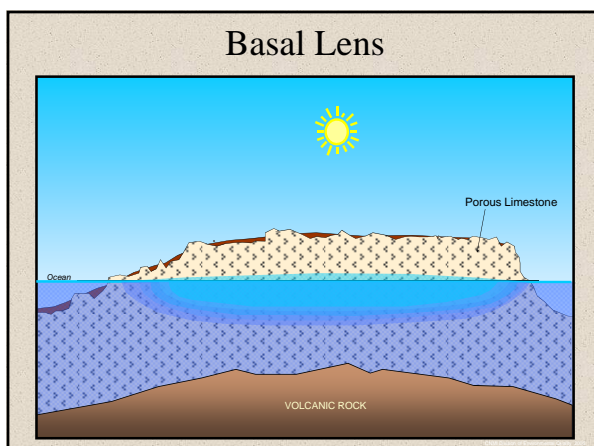- Reality check:

Basal Lens:

- Anatomy of lens
- Theory: Depth of lens = depth to "mid point" of transition = 50% seawater

Basal Lens:

- Anatomy of lens
- Theory: Depth of lens = depth to "mid point" of transition = 50% seawater
- Reality: "potable" lens much thinner; transition more rapid

Basal Lens

Hydrologic Cycle

Hydrologic Cycle

"Basal Lens"

aquifer

EVAPOTRANSPIRATION

Porous Limestone

Ocean

RECHARGE

VOLCANIC ROCK

Hydrologic Cycle

"Lens" system dependent on rainfall:

If rain stops, lens shrinks…

Porous Limestone

Ocean

VOLCANIC ROCK

Basal Lens "water balance":

- Rainfall = 80 in/year
  - Losses to:
  - Runoff
  - Evapotranspiration

- Infiltration:
  - ¼ to 1/3 rainfall (23")
  - 30 to 45 inches;
    - Say 40 inches

- 91 million gallons per day

PHILIPPINE SEA

PACIFIC OCEAN

MUNICIPAL WELL FIELDS ON SAIPAN

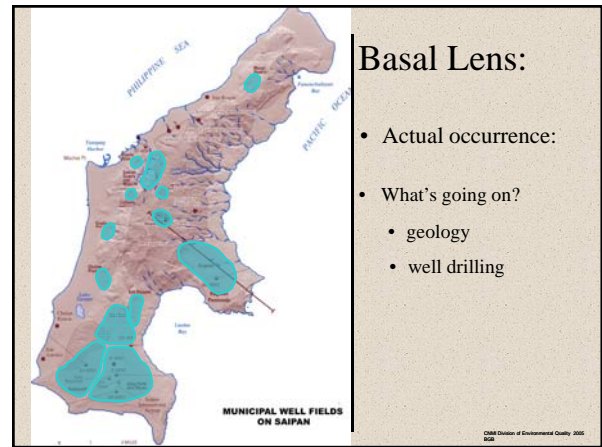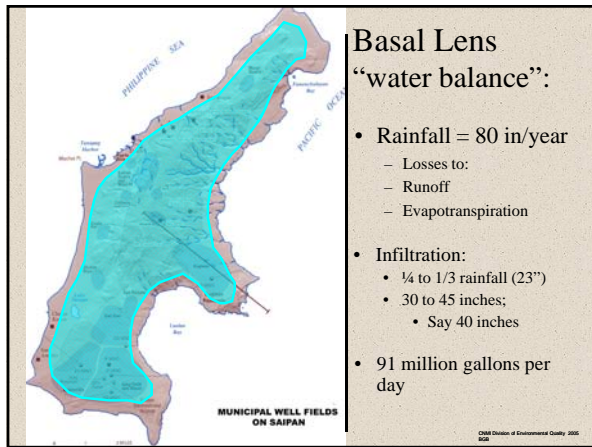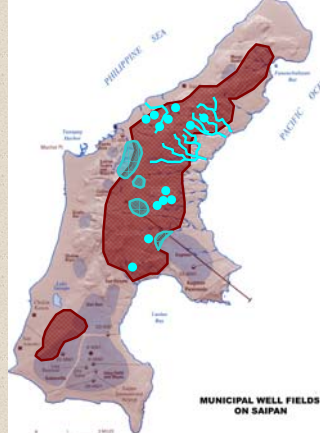CNMI Division of Environmental Quality 2005 RGB

Basal Lens:

- Actual occurrence:

- What's going on?
  - geology
  - well drilling

PHILIPPINE SEA

PACIFIC OCEAN

MUNICIPAL WELL FIELDS ON SAIPAN

CNMI Division of Environmental Quality 2005 RGB

Volcanics:

- "core" of island;

- "blocks" basal lens at sea level

PHILIPPINE SEA

PACIFIC OCEAN

MUNICIPAL WELL FIELDS ON SAIPAN

CNMI Division of Environmental Quality 2005 RGB

High Level and Parabasal

"High Level" and "Parabasal" Groundwater

Porous Limestone   well   well   Spring
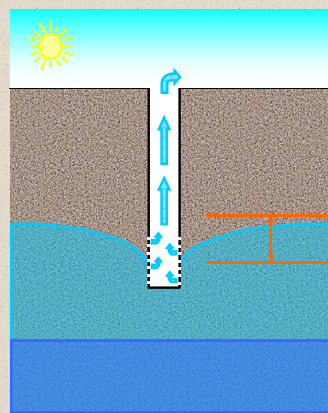
Ocean

High level or "perched" aquifer

Parabasal aquifer

VOLCANIC ROCK

High level water:
- Perched aquifers
- Para-basal aquifers
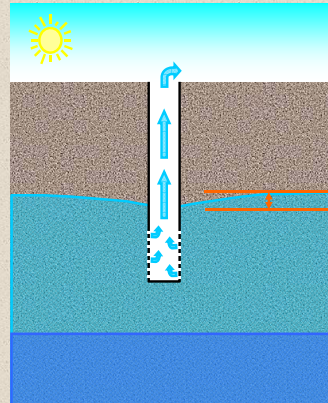- Springs
- Streams
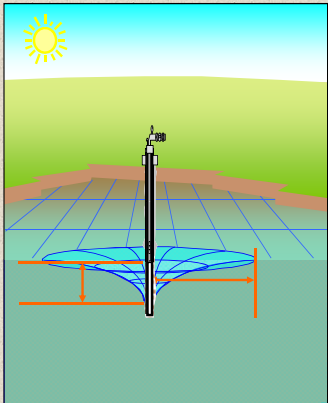
MUNICIPAL WELL FIELDS ON SAIPAN

Water Wells:
- How much can you pump?
- "Drawdown"
- Cone of Depression
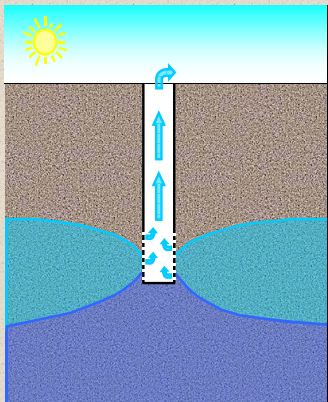- A function of permeability and pump rate

Water Wells:
- "Radius of Influence"

  = radius of cone of depression

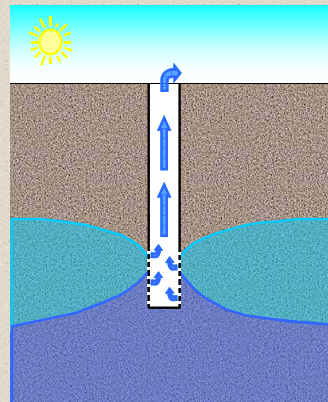- A function of permeability and pump rate

Water Wells:
- Example:

  LIMESTONE
- Very small drawdown
- Can pump 100s of gallons per minute!
- So why are most wells pumped only 10 gpm?

Water Wells:
- "Upconing"

  or:

- Salt water intrusion

- A function of **lens thickness, well depth,** permeability, and pump rate

Well Depth:
- Too close to transition depth:

- Production rate will always be limited

Well Depth:

- In transition zone:

- Never had a chance!

Well Depth:

- Ideal:
  - Shallow penetration "skims" fresh water from surface

- Production can be maximized
  - Still limited by aquifer/recharge characterisitics

Wells:

- Where can a "good" well be drilled?

Wells:

- How much water can actually be produced?
- Theory:
  - 91 million gallons per day ?
- Actual withdrawal:
  - 13.6 mgd from CUC; wells & springs
- Needed:
  - 11 mgd