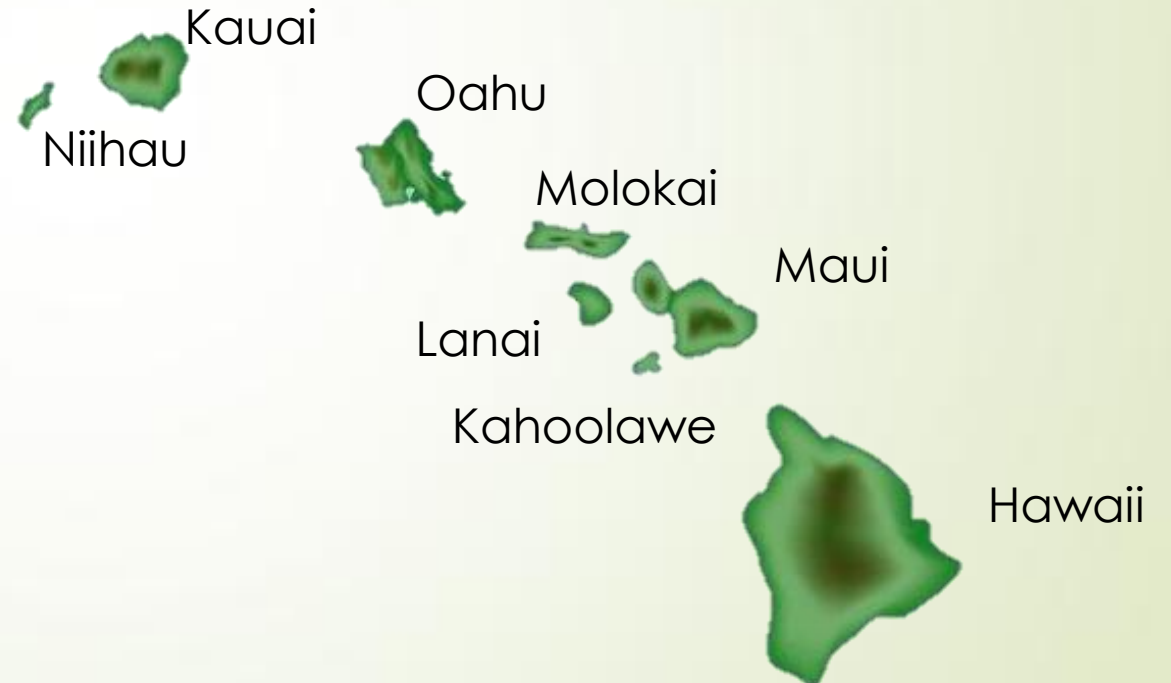


The Origin of the Hawaiian Islands and Its Biota



By Jazzmin Umemoto

What The Paper is About

- 4 major theories on origin of Hawaiian Islands
- Rigid earth vs mobile earth
 - Rigid Earth: Fixed continents
 - Mobile Earth: Continents can shift
- 1st theory: Rigid earth
- 2nd theory: Rigid earth
- 3rd theory: Mobile earth
- 4th theory: Mobile earth





The First & Second Rigid Earth Theories

- Proposed by Newton, elaborated by Kelvin, widely accepted by geologists in the northern hemisphere
- Contracting by cooling, compaction, and extrusion of volcanic rocks and gases
- Explains the compressional forces observed in mountains very well
- Expanding by radioactive heating or by a decrease in the gravitational constant
- Radioactive heating is unprovable: unknown amounts of uranium, thorium, and potassium in the earth
- Expansion offers a good explanation of the tensional forces in the mid-ocean ridges



The Third and Fourth Theories

- ▶ Mobile earth with continental drift
 - ▶ Wegener believed it was due to rotational forces on spheroid
 - ▶ Most didn't believe, but agreed drift was only way of explaining results of measurements of rock magnetism
-
- ▶ Mobile earth, mantle of earth is convecting
 - ▶ Highly probable if Rayleigh's criterion for convection applies
 - ▶ Currents of convection cells rise and separate under mid-ocean ridges producing tension, come together and sink under continental mountains producing compression
 - ▶ Better mechanism for continental drift than Wegener



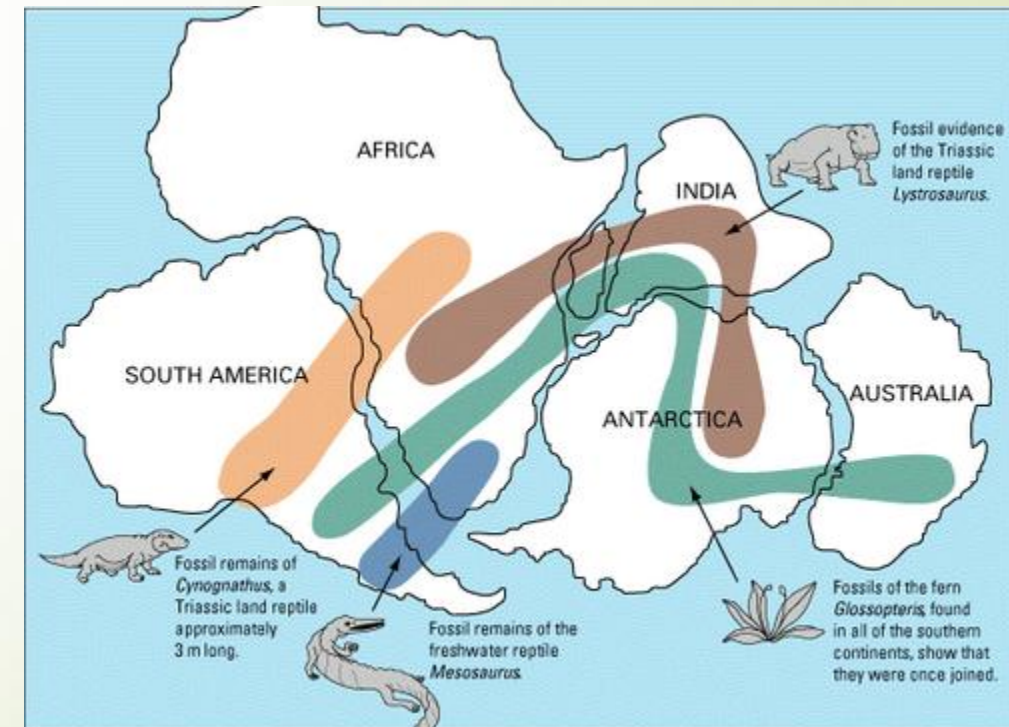
Goal of the Paper



- ▶ All four theories have some kind of flow in interior to account for the slow rise of regions
- ▶ Too little is known about the earth's interior and the gravitational constant to decide between the views on general grounds
 - ▶ Analysis of features are necessary before anything can be applied. Observations have been made, but were not made in the appropriate scale or in enough places
 - ▶ Physicists' are too broad and geologists' are too narrow
 - ▶ Most observations have been confined to the accessible $\frac{1}{4}$ of the earth's surface
- ▶ New data strays away from a rigid earth
- ❖ One class of features: explain origin of linear chains of islands (Hawaii) and explain it in terms of convection vs a rigid earth

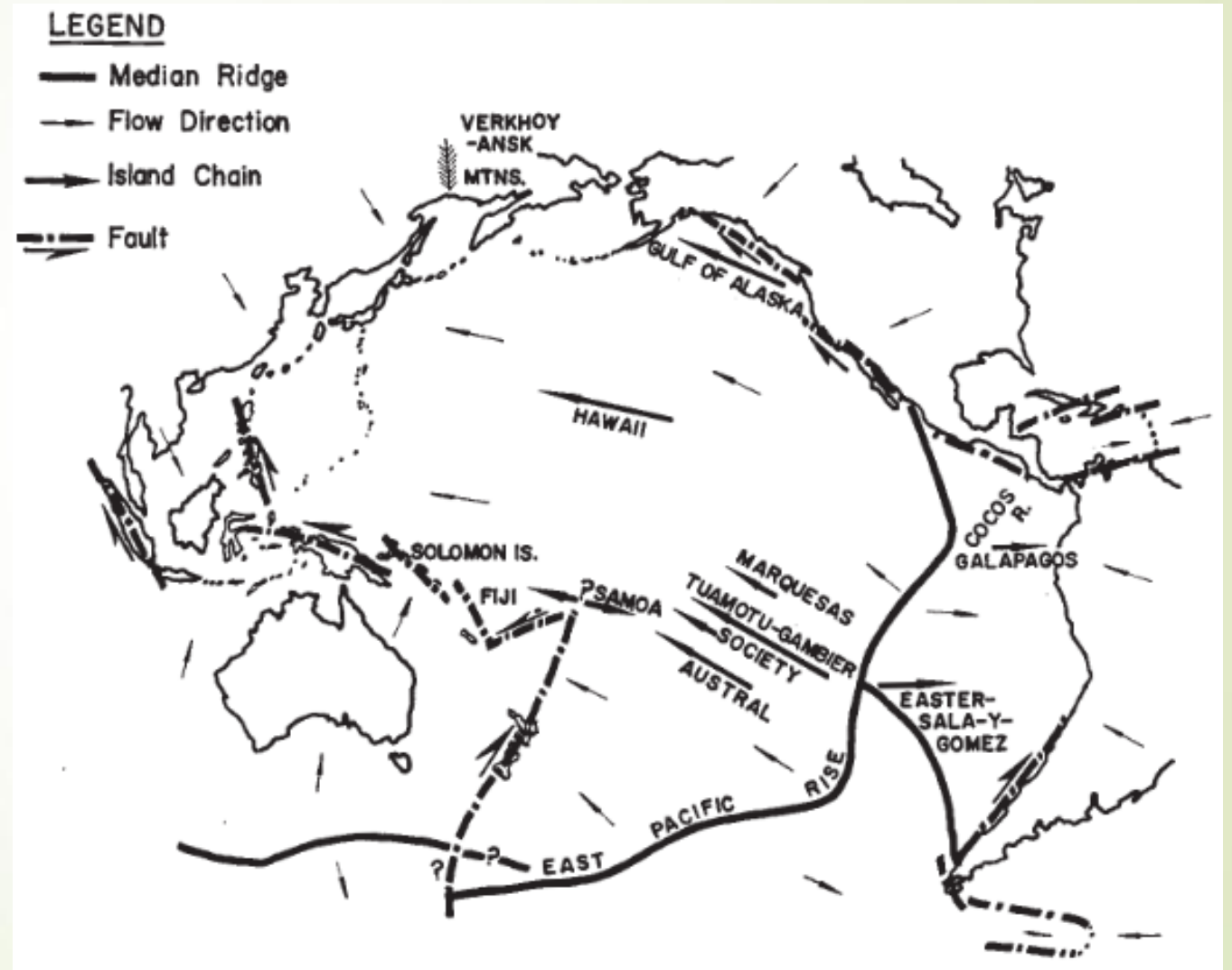
Rigid Earth Theory Disproved

- Billions of years, Earth = rigid/static (not able to bend/move)
- Now, Earth's crust can bend like a tough plastic before breaking (plasticity)
- Too many similarities between South America and Africa
 - Jig-saw puzzle way that they fit together
 - Dinosaur species found on both continents
 - Plant fossils where seeds weren't able to cross the ocean
- Fossil of *Glossopteris* found in southern parts of:
 - South America, Africa, India, Antarctica, Australia



Nine Chains of Islands

- Seven of Nine on large ridges moving northwest
- Six have active/recent volcanos on east island and get progressively older away from East Pacific Rise
 - Due to ascending/spreading convection current
- Islands on other side of the EPR are mirror images – increase in age away from EPR



Convection Currents

- Convection: transfer of heat due to movement of molecules within gases/liquids
- CC in ocean: heated fluid expands, becomes less dense, rises. Pulls cooler fluid to replace it = circular current only stops once heat is evenly distributed
- CC in earth: molten rock deep in earth circulates by CC
 - Semi-liquid state, rises up away from the mantle, loses heat into the earth's crust, becomes cooler and more dense, sinking back down to the core

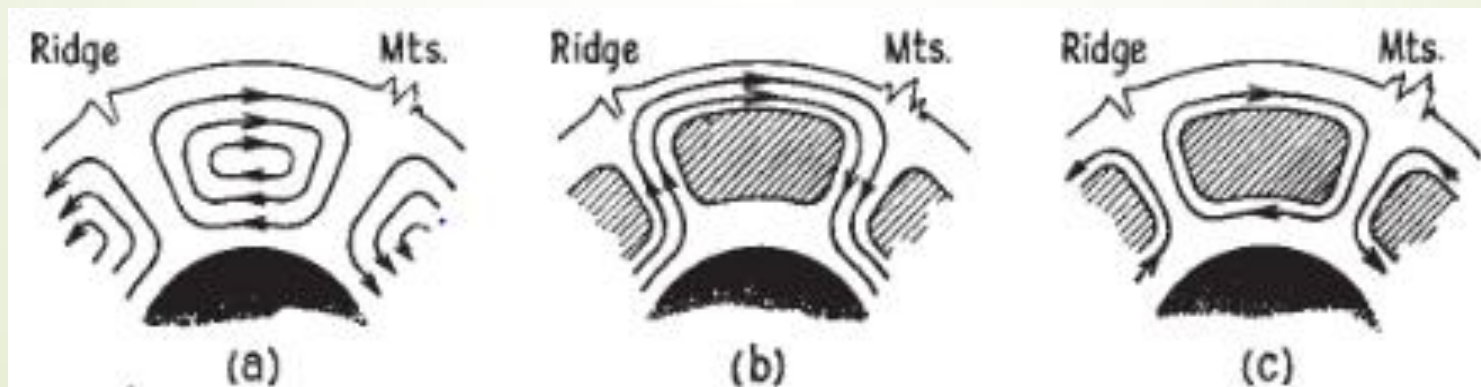
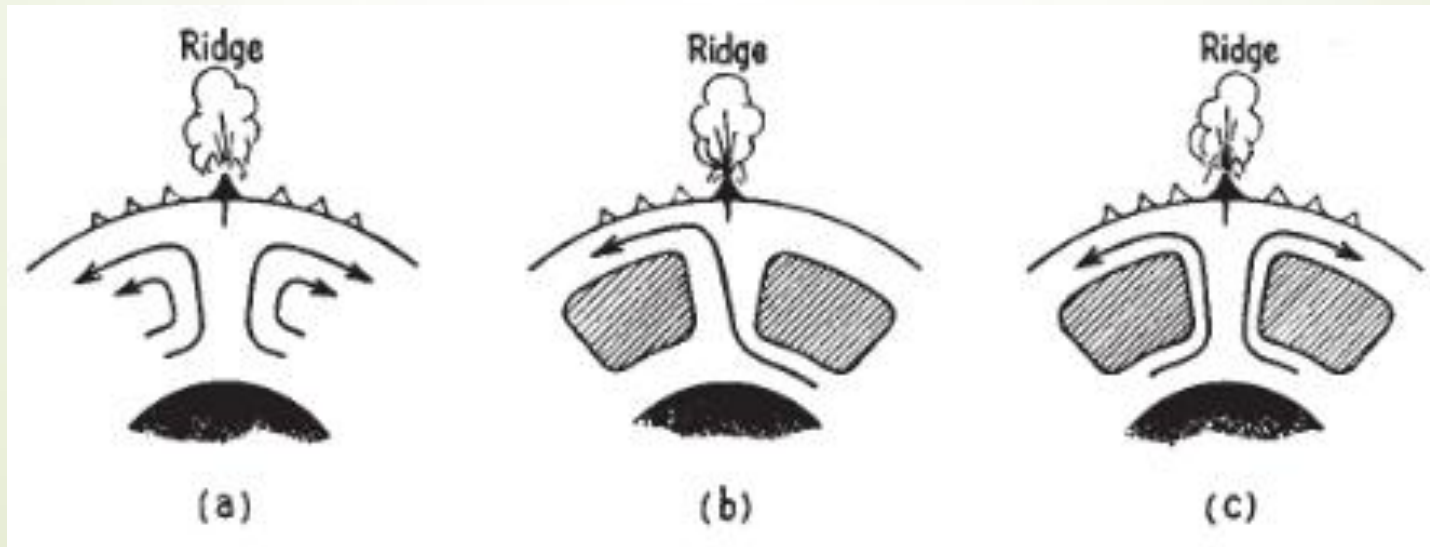


FIG. 2. Three possible modes of convection in the Earth's mantle.

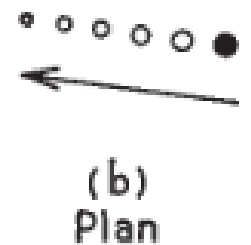
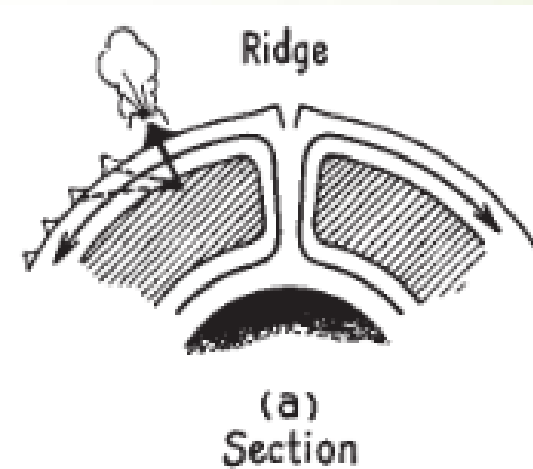
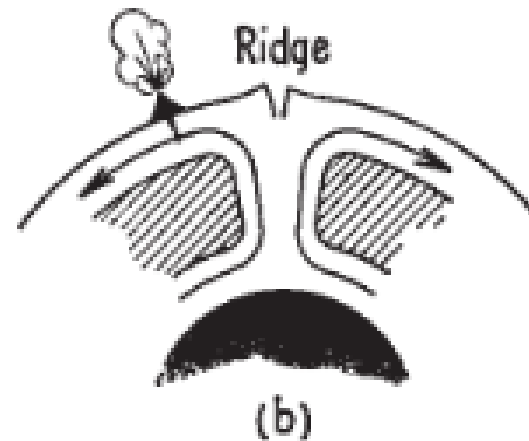
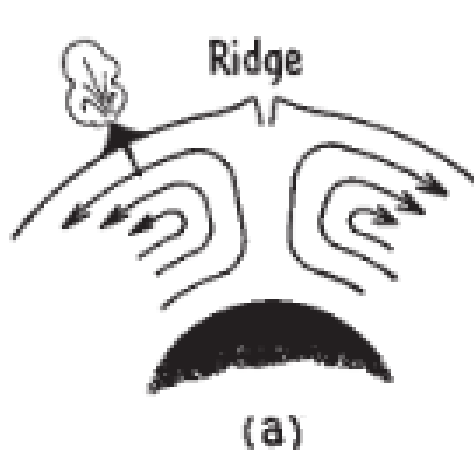
Possible Patterns of Convection

- Volcanos form over a rising vertical current, constant heat source, so origin is always the same
- Chains formed by horizontal flow of currents
- Further away from ridge = older volcano



Possible Origin of Hawaiian Islands

- If lava doesn't come from rising current, one volcano will be created
- If lava comes from stable core, then it can give rise to a chain
 - CC in upper mantle must be a jet stream type





Goal of Paper

- Estimated original height to calculate
 - Growth
 - Subsidence
 - erosion
- Recreated the changing elevation over time
- Determined spaces between volcanos
- Allowed testable hypotheses on the history of evolutionary lines in Hawaii
- Origin of Hawaiian Biota
 - Understanding the islands origin, made it possible to calculate growth and movement

Geographic Information Systems

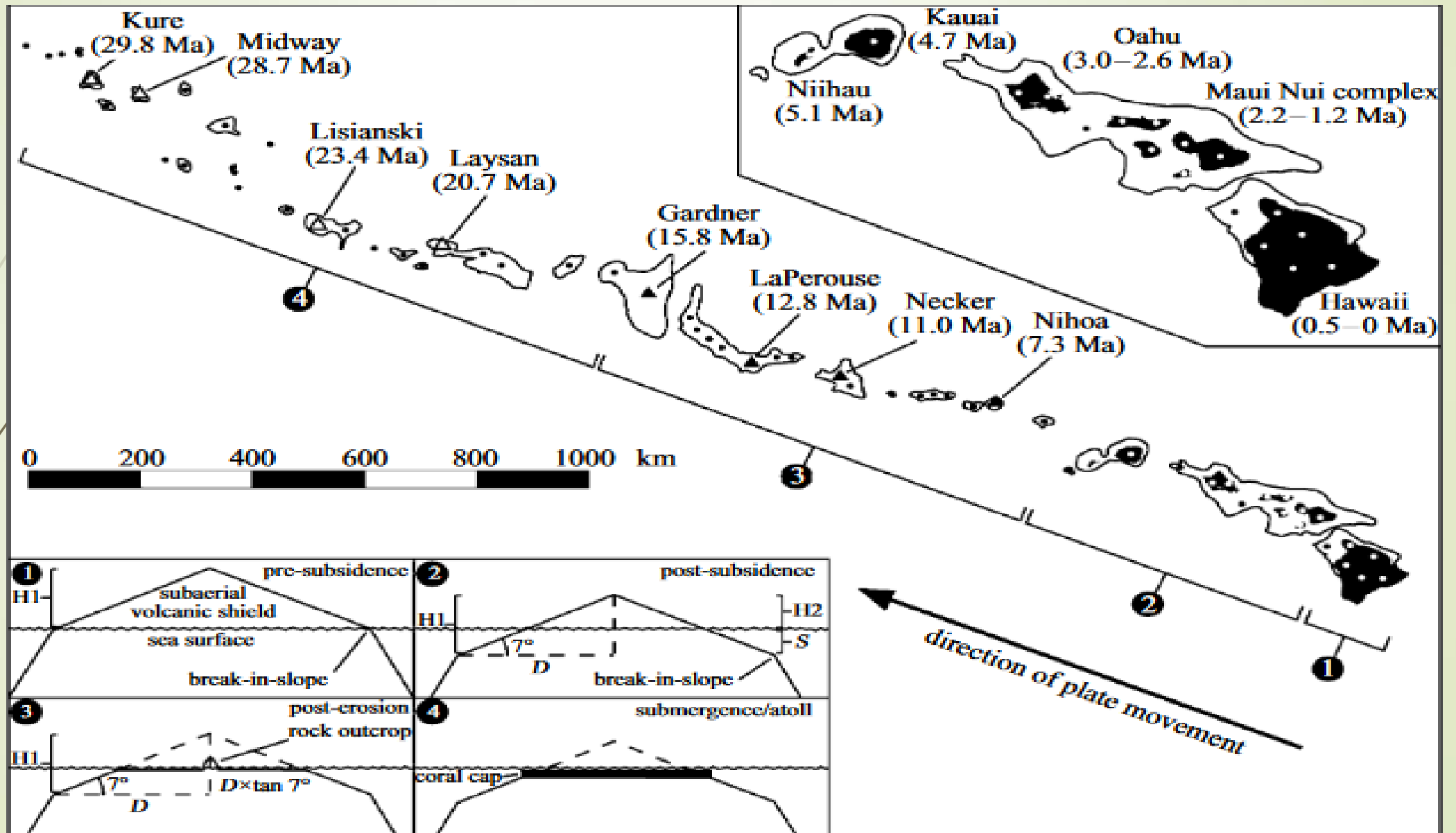
- Original Height: Sonar to estimate the maximum shoreline
 - Adjusted Clague's (1996) summit positions and ages
 - Found average angle between the shortest distance from the summit to the maximum shoreline: 7° - 95% certainty
- Growth Rate: Volcanos of Hawaii reach max elevation around $\frac{1}{2}$ myr
 - Subtracted $\frac{1}{2}$ myr from estimated age and made linear growth formula
- Subsidence Rate (Depth of Slope): Used amount of subsidence known for main islands to make an equation to generalize an amount of subsidence for other volcanos



Geographic Information Systems Continued

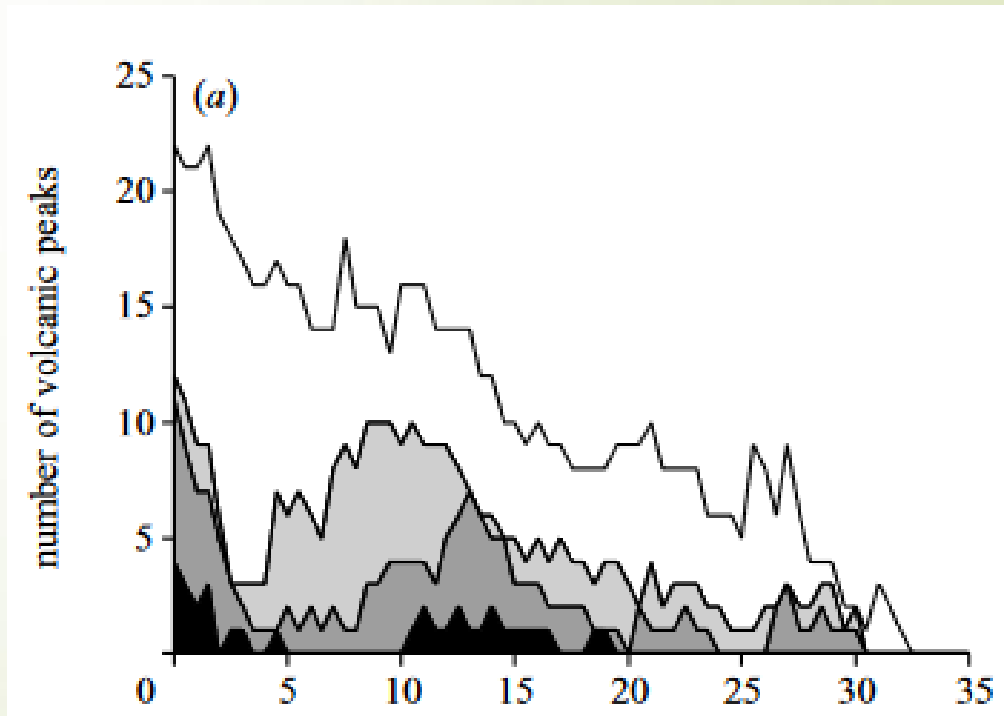
- Erosion Rate: Plays big part when subsidence has slowed
 - Estimated elevation after subsidence – current elevation = amount of erosion.
 - Determined average rate of erosion per volcano.
 - Not a constant rate, not enough data to predict how it could change over time
- Life History Reconstruction: Applied estimated rates for each period in life cycle in regard to estimated age/height
 - 32myr ago = Upper limit for spreading/evolution of biota
- Volcano Spacing: Two methods
 - distance between maximum shorelines (minimum distance possible)
 - distance between summits (dispersal distance of land species)

Graph of Listed Findings



Results

- Gardner formed 16ma – largest precursor island
- First peak period (18 – 8 Ma): multiple volcanos over 1000m = extensive archipelago
- Intervening period: Smaller islands formed before Kauai resulted in a smaller archipelago
- Islands after Kauai were large, the last 3Myr there have been numerous islands over 1000m
 - More area than ever in the last 32 Myr (More space for biota)
- Variation of spacing between the volcanos shows a pattern of closeness during peak periods and distance during intervening periods



Discussion

- Volcano's area/range have direct relationship with height: peak periods = best opportunities for colonization/speciation
- Sonia Juvik (Atlas of Hawaii) estimated frequencies (net rates) of colonization
 - Less than 1 Myr for birds
 - 98,000 years for plants
 - 68,000 years for insects
- Actual rates cannot be determined: extinction rates are not known
- Based on distance/available range, biota could migrate (older to younger)
- Peak periods
 - Islands closer together = higher migration rates and vice versa during intervening periods
- Caused bottleneck (reduces population to small amount, less variation)
- Lower land and water species
 - Less severe bottleneck due to shorter islands being more numerous/closer together

Discussion Continued

- Bottleneck limited population
 - Most present species pool on islands came from lineages arrive/diversified recently
- To test:
 - *MRCA*: When taxa started to diverge from one another (Not time of colonization)
 - MRCA + outside relative: usually closest outside relative not known/extinct, based on more distant relative (older than actually time of colonization)
- 12 out of 15 multi-species lines have separated since Kauai
 - Of 12, 3 have separated from outside relatives (5 Ma)
 - Rest possibly arrived in archipelago before
- 7 Single-species lines: diverged from outside relatives (5 Ma)
- Plant lineages show low deviation = fast divergence from recent colonization
- 5 single-species bird lines are genetically similar to outside = recent arrival
 - No evidence of bird lineage colonizing in archipelago



Conclusion

- All biota have been shaped by recent speciation
- Views are skewed due to limited knowledge of precursor lineages
- Likely, few transfer events from former big islands and rapid divergence that led to present set of species
- Around Hawaiian Islands, environment and climate changes occur faster than speciation can respond = biotas in state of disequilibrium
- Due to more dynamic environment, only rapid speciation can explain the rich/unique biota – did not colonize in archipelago