**Lake Clark**

1. Lake Clark National Park …
2. … is located within the same general region as Katmai and Kenai Fjords National Parks, so it should come as no surprise that it falls within the great Aleutian subduction zone. You should be able to judge from its position whether it is part of the volcanic arc, forearc basin or accretionary wedge.
3. You did pick volcanic arc, didn’t you? And there are two active composite volcanoes in the park to prove it - Iliamna and Redoubt. Since Iliamna has not erupted since the 1800’s and Redoubt erupted in 1990, much of this lesson will focus on the 1989-1990 eruption of Redoubt.
4. But first let’s take a look at the park’s 45-mile-long namesake, Lake Clark.
5. It’s been called one of the most beautiful bodies of water in the world. You can see from the sweeping U-shaped slopes bordering the lake that this valley was carved by glaciation. More importantly, the linearity of the valley is because the glacier eroded rock weakened by a major fault zone.
6. You can see on the geologic map that the Lake Clark fault zone runs along the length of Lake Clark. The fault marks the place where a major tectonostratigraphic terrane known as the Peninsula Terrane was accreted against the edge of Alaska.
7. Tectonostratigraphic terranes are fault-bounded packages of rocks, of regional extent, that have a geologic history unique from surrounding areas. The Lake Clark Fault zone represents a “suture” where two such terranes are joined. *Amalgamation* happens when two or more terranes are sutured before being *accreted* to the edge of a continent. The age of amalgamation or accretion must be younger than the rocks within the terrane and older than any rocks deposited on top of the suture. Volcanic arc magmatism can also help constrain the age of accretion or amalgamation by emplacing plutons within adjacent sutured terranes. Since such plutons will be of the same general age in adjacent terranes, they are known as stitching plutons because they indicate that the terrains had been sutured prior to the time of pluton emplacement. Using these kinds of relationships, geologists have determined that the Peninsula Terrane accreted sometime in the late Cretaceous to early Cenozoic.
8. Clark Lake is the most tectonically significant in the park, but the aptly named Turquoise Lake is perhaps the stunningly beautiful.
9. The gorgeous turquoise color here …
10. … should not be confused with that of tropical waters, where the water’s clarity allows the light color of the sand bottom to show through and lighten the deep blue of the ocean.
11. The water in Turquoise Lake is definitely not clear. In fact it is loaded with fine suspended particles derived from glacially pulverized rock. The particles, known as rock flour, are so fine, that despite the calmness of the lake, do not settle out. Like air molecules, the particles are so small that they will only scatter the shortest visible wavelength of sunlight, which for the most part is blue.
12. Turquoise Lake is fed by the combined melt water from dozens of glaciers that scour away in park’s higher elevations. Because of the large sediment load these streams carry, they are aggrading. Coarse sediment settles out as numerous bars, forming a braided stream pattern, whereas the fine rock flour remains suspended.
13. You can tell from the color of Twin Lakes that it receives mostly non-glacially derived runoff.
14. There are many other lakes in the park, none of which are accessible by road. The tundra-covered hills remain beautifully pristine. Well that’s about all the lacustrine tranquility I can stomach.
15. Let’s blow up a volcano! It will have to be Redoubt, …
16. … because as you can see from the irregular shape of Iliamna volcano that it hasn’t erupted in a while and glacial erosion is vigorously trying to wear it down.
17. Redoubt is different. Although the summit is breached by the massive “Drift Glacier”, Redoubt retains much of the conical shape of a classic composite volcano. Note that Drift Glacier leaves its glacial trough and becomes an unconfined piedmont glacier. This glacier will play a major role in the eruptions of …
18. … 1989 and 1990. Much like Mount Lassen, the initial phase of the Redoubt eruption of 1989 emitted mostly steam and ash. This probably occurred as magma made its way to the surface by fracturing rock. Snow melt entered the hot, fractured rock and flashed to steam, which explosively widened the fractures and thus helped bring the magma to the surface.
19. Eventually enough rock had been blasted away in this fashion to create a conduit for the magma to reach the surface and form a dome.
20. The 1989 to 1990 eruptions of Redoubt Volcano were characterized by the repeated growth and destruction of lava domes in the summit crater. This view shows the north face of the second largest lava dome, which was destroyed during an explosive eruption on February 15, 1990.
21. Avalanching of hot debris from disintegrating lava domes caused extensive melting of the glacier draining the summit crater and produced deeply incised channels with steep ice walls.
22. During the eruption of Redoubt Volcano on December 15, 1989, hot ejecta falling onto the upper flanks of the volcano produced avalanches of snow, ice, melt water, and pyroclastic debris to form an unusual ice-rock diamict (meaning very poorly sorted sediment). In this view, the diamict is approximately 4.5 m (15 ft) thick and caps ice of the piedmont lobe of Drift glacier. Overlying the ice-rock diamict lie sand to gravel-sized pyroclastic flow deposits from eruptions between January and March of 1990.
23. Here geologists examine steaming pyroclastic-flow deposits from the March 23, 1990, eruption of Redoubt Volcano that came to rest on the margin of the piedmont lobe of Drift glacier. The collapse pits seen here resulted from funneling of debris into crevasses and holes in the buried surface of the glacier. Darker areas are chunks of glacial ice melting and incorporating into the deposit.
24. Larger blocks of glacial ice were carried many kilometers downstream by lahars during the 1989 to 1990 eruptions of Redoubt Volcano. This kind of activity lasted until April 21, 1990 …
25. … when this happened! The ascending eruption cloud from Redoubt Volcano had a decidedly nuclear look to it as it mushroomed into the stratified troposphere. Although ash fall is more of a nuisance than a hazard for those on the ground, …
26. … for airlines the proximity of the Aleutian volcanic arc to North Pacific air routes is one of the principal hazards associated with volcanoes in Alaska, because jet engines can malfunction when loaded with ash.
27. At that’s precisely what happened to KLM Flight 867 on December 15, 1989 during one of the much smaller eruptions that preceded the main blast seen in this photo. The Boeing 747 was descending into Anchorage International Airport when it flew though a thick cloud of volcanic ash from Mt. Redoubt. In Alaska, December days are short and nights are long so the captain probably could not clearly see the ash. All four engines stalled and the standby electrical system failed. After descending more than 14,000 feet, the captain and crew were finally able to restart the engines and safely land the plane. The ash caused more than $80 million in damage to the plane, but no lives were lost.
28. If you look closely at the April 21st eruption shown here, you can see that only a small plume of steam rises from the summit crater. Note that the giant ash-laden, mushroom cloud did not rise from the vent, but rose from avalanches of hot debris (pyroclastic flows) that cascaded down the north flank of the volcano. This is because the pyroclastic flow landed on snow and ice that vaporized into stream, which helped buoy the hot pyroclastics into the much cooler and therefore denser atmosphere.
29. Ice that did not vaporize melted and mixed with the pyroclastic material to create massive lahars that surged across the Drift River valley seen here. Except for the two bedrock islands that are visible at bottom center, lahar deposits from numerous eruptions cover the valley floor.
30. Lahars from the 1989 to 1990 eruptions of Redoubt inundated this structure near the mouth of Drift River, 35 km (22 mi) from the volcano.
31. One of the principal facilities at risk during the 1989 to 1990 eruptions of Redoubt Volcano was the Drift River Oil Terminal located at the mouth of the Drift River, 35 km (22 mi) northeast of the volcano. The picture emphasizes the long reach that lahars have.
32. After the big eruption of April 21, 1990 Redoubt Volcano continued to emit steam and volcanic gas for a few months …
33. … associated with the emplacement of a final lava dome. A fractured lobe of blocky lava is visible at center. Steam from the interaction of melt water with hot rock billows from the margins of the lava dome. Remnants of glacial ice with a coating of gray ash surround the dome.
34. The highly irregular, final lava dome of the 1989 to 1990 series of eruptions of Redoubt Volcano was composed of andesite lava. Released from magma crystallizing at depth, yellow sulfur deposits are visible on a block of lava at center of view.
35. Redoubt Volcano remained quiet for nearly 20 years…
36. …then sprang to life in 2009 with the emission of notable amounts of steam and a couple dozen ash cloud eruptions. Although none of these was as intense as those in 1989, once again lahars surged down Drift Valley all the way to the ocean …
37. … and domes formed in the summit crater.