**Isle Royale National Park**

1. Isle Royale, or ile-ROY-ul as most Midwesterners pronounce it, is the largest island in Lake Superior.
2. Located in beautiful Keweenaw county …
3. … whose two parts complete the geologic structure of which Isle Royale is half. More on that later.
4. The park’s entrance sign hints at some of its features. On the left is some kind of wood, as the island is covered with spruce, birch and cedar. On the right is a copper veneer that tells of the abundant copper deposits in the area. That the sign is shaped like a wheel is perhaps a bit of irony, because as an international biosphere reserve, absolutely no wheeled vehicles of any kind are allowed on the island.
5. Hiking and boating are about the only way to get around. Mostly that’s because of park policy, but the island’s topography is not wheel-friendly either.
6. Isle Royal’s uniquely elongated ridges are the product of mostly glacially-cause differential erosion of …
7. … a Proterozoic sequence of interbedded lava flows and associated sedimentary rocks. Ridges correspond to layers of particularly resistant basalt.
8. Along the shorelines where wave erosion outpaces soil formation …
9. … the black, fine-grained basalt is visible.
10. Good outcrops also occur where glacial erosion was most severe – like on the ridge crests where the most erosion-resistant basalt occurs. These basalts formed as extremely fluid lava flows that spread laterally over vast areas.
11. The wrinkled surface of this ancient lava flow from Isle Royale bears witness to the fluidity of the lava. Known as pahoehoe, such lava forms when a thin, partly-solidified lava skin is stressed by the flow of highly fluid magma beneath.
12. Columnar basalt also testifies to the lava’s fluidity. Fluid lava spreads-out evenly over vast areas, so when cooling occurs, contraction is uniform and internal. The process is much like how a layer of dried mud cracks, only a lava flow is much thicker, so the deeper cracks form columns.
13. Between the elongated ridges, a more easily eroded *amygdaloidal* basalt is found.
14. Amygdules refer to gas bubbles (vesicles) that have been filled with minerals.
15. The minerals filling the vesicles are typically some type of zeolite, which refers to a group of hydrous aluminosilicate minerals. Zeolites have an interesting list of uses that includes being the main component in water softeners. Often the zeolites more resistant to weathering than the surrounding basalt, …
16. … so some of the island’s beaches are made of abundant amygdule pebbles …
17. … like these beauties comprised of the rare mineral Thompsonite.
18. Locally there are felsic dikes intruded into the basalt. The combination indicates bimodal magmatism, which is an important indicator of the tectonic environment in which these rocks were formed.
19. Also indicative of that environment are the island’s sedimentary rocks. The most notable of these, the Copper Harbor Conglomerate, is relatively feldspar rich. That, combined with the bimodal volcanism, should give you a pretty good idea as to the tectonic environment.
20. But let me add one more piece to the puzzle – geologic structure. Lava flows and sedimentary rocks all have a consistent southeast dip direction.
21. Note also that Copper Harbor Conglomerate outcrops on the southeastern side of the island and that the southeasterly dip of these rocks is toward …
22. … the Keweenaw peninsula.
23. The same rock units that occur on Isle Royale occur on the Keweenaw Peninsula, on the peninsula the order and dip direction is reversed.
24. Furthermore the peninsula rocks dip more steeply than those on the island.
25. Putting it all together now in this cross section, you can see that Isle Royale and the Keweenaw Peninsula are two sides of a giant downward fold called a syncline. The syncline is slightly asymmetrical because the rocks at Keweenaw dip more steeply. The syncline and associated reverse faults formed by compression during the proterozoic Grenville Orogeny.
26. Removing the effects of Grenville compression returns the structure to its configuration during the time when the volcanic and sedimentary rocks where deposited. You can see that the compressive episode made reverse faults out of what were originally normal faults. This structure should look pretty familiar to you by now.
27. OK now, put it all together, bimodal magmatism and feldspar-rich sedimentary rocks all forming within a basin bounded by normal faults …. What does it all suggest?
28. I know you probably had the answer back at bimodal magmatism, but it was fun to show that all the classic features of continental rifting are found at Isle Royale.
29. The reason why the synclinal structure existed to some extent before the Grenville compression affected the region, …
30. … following the outpouring of huge amounts of lava, the mantle source becomes somewhat evacuated, which combined with the weight of the thick lava flows…
31. … results in the subsidence of the basin and subtle down warping of the lava flows. During lulls in volcanic activity feldspar-rich gravels would get carried into the basin from the erosion of the continental rocks bordering the basin.
32. Another batch of fresh magma from the hot spot erupts and the cycle starts over again.
33. It is tempting to link the Lake Superior Syncline to the downward folded rocks of the Michigan Basin, …
34. … but the age of folding in the Michigan Basin is Paleozoic rather than Proterozoic and style of deformation is different too. The bulls-eye pattern of rock ages indicates a bowl-like structure for the Michigan Basin …
35. ... whereas the Lake Superior Syncline is more like a long trough.
36. Because that trough is filled with a lot of relatively dense basalt, the pull of gravity is a little bit stronger there. The red areas on this map indicate where the pull of gravity is abnormally high. Note they form a belt that runs from Lake Superior southwestward across the heart of the Midwest. The gravity anomaly is particularly strong in central Iowa …
37. … where most residents are completely unaware of the oppressive gravitational hazard that lies below.
38. Sadly, there is little that can be done for the most severely affected.
39. The basalt-filled rift valley also shows up on magnetic surveys because basalt contains a lot of the highly magnetic mineral magnetite.
40. We have only recently become aware of how serious this environmental threat is.
41. Sedimentary rocks completely filled the failed rift, so there is little current topographic expression of the allochogen - other than Lake Superior where glacial erosion removed the rift’s softer sediments and helped form the deep basin now filled with the largest freshwater lake in the world.
42. During the interval when the rift was volcanically active, or shortly thereafter while those rocks were still warm, native copper deposits where emplaced.
43. The term native here implies that the copper is not compounded with any other element. Virtually pure copper is often found filling the amygdules …
44. … or just about any crack or pore in the basalt or conglomerate.
45. Some of the largest native copper masses ever found were mined from Isle Royale mostly in the 1870’s …
46. …. as well as several museum quality specimens that illustrate copper’s crystal habit and …
47. … variable forms.
48. Although no single theory for the origin of the copper deposits has been universally accepted, most involve the action of circulating hydrothermal solutions. These either brought copper-bearing solutions towards the surface from crystallizing magma at depth or leached the copper from the basalts themselves and re-precipitated it in pore spaces where the hydrothermal solutions cooled.
49. Throughout the Paleozoic, Mesozoic and Cenozoic the area was tectonically inactive and underwent a prolonged period of erosion …
50. … which essentially peneplaned the region. During the Pleistocene epoch, thick continental glaciers extended from Canada across this area …
51. … to as far south as central Illinois.
52. The direction in which the continental ice sheets moved across Isle Royale was almost exactly parallel to the strike of the Proterozoic basalts and conglomerate there.
53. So glacial erosion enhanced the island’s preexisting grain.
54. There are numerous places on the island where one can where glacial action has polished ...
55. … or grooved rock surfaces.
56. As glaciers move across resistant rocks, asymmetrical ridges form because abrasion occurs on the side of ridge from whence the glacier comes (Stoss side), whereas ice plucking occurs on the Lee side. Such ridges are called Roche Moutonnée (rock sheep) …
57. … because they resemble sleeping sheep.
58. Supposedly Roche Moutonnees formed along the most resistant lava flows of Isle Royale …
59. … but I could find no obvious examples.
60. Drumlins are another glacial landform which is alleged to exist on Isle Royale. Although they abound in nearby Wisconsin, again I could find no Isle Royale examples to show you.
61. They form in unconsolidated material - not rock, and they have the opposite asymmetry as Roche Moutonnees. The lee slope here is more gentle.
62. Unlike the generally solitary Roche Moutonnees, drumlins typically occur in clusters.
63. Although glaciers where the dominant erosional agent which shaped the island, its shorelines were modified by wave action.
64. Yes, there is surf in the Great Lakes! Remember that Lake Superior is the largest fresh water lake in the world …
65. … and some pretty viscous storms blow across it.
66. Believe it or not this is Lake Superior …
67. … and so is this ….
68. … and this. So you can see that there are days when wave erosion is going to be significant.
69. Wave eroded features occur on the most exposed shores and include sea cliffs, caves …
70. … and countless sea stacks, which are remnants of wave eroded points.
71. Because they where detached from the point by wave erosion, sea stacks tend to have steep sides.
72. Finally, wave erosion tends to level the shallow, near-shore lake bottom while building a gravel berm on the shore. When the water level drops and/or the land uplifts, these features are exposed indicating the position of the former shorelines.