Yosemite 2

1. The batholithic rocks that formed beneath the volcanic arcs have ages that cluster into three distinct groups. The oldest group is about 210 to 150 million years old, or late Triassic to Jurassic.
2. These oldest of the batholithic rocks are shown in purple here and tend to be mostly diorite and gabbro.
3. They are intruded by the younger and generally more felsic plutonic rocks shown in the darker pink here…
4. … which belong to the second group of batholithic rocks, mostly represented by the Western Intrusive Suite. At 120 to 100 million years old, the Western Intrusive Suite is Cretaceous in age.
5. The massive granite monolith of El Capitan is representative of the Western Intrusive Suite.
6. The El Capitan Granite is a beautiful rock comprised of slow-cooled, clearly visible crystals.
7. Typical of granitic rocks, it contains few dark minerals and is mostly quartz (gray glassy looking grains), ….
8. … and alkali feldspar (white grains).
9. The few ferromagnesian minerals here are mostly biotite mica (black grains).
10. The same period of magmatism also produced a few relatively mafic rocks most notably represented by the so-called “Map of North America”…
11. … which is a diorite intrusion on the east face of El Capitan.
12. Viewed from the right angle and degree of tolerance …
13. … the resemblance, albeit crude, is obvious. Given the position of Baja California, perhaps this is a version of what North America will look like in the geologic future.
14. The Western and Minor Intrusive Suites were emplaced early in the ocean-continent collision known as the Nevadan Orogeny. Since the accretionary wedge was relatively small and the angle of subduction relatively steep at the time, subduction-generated magmatism occurred fairly close to the trench.
15. But the accelerating westward motion of the North American plate, combined with a growing accretionary wedge, flattened the subduction angle …
16. … such that by the late Cretaceous, arc magmatism had shifted eastward and emplaced the “Tuolumne Intrusive Suite”.
17. This suite of plutonic igneous rocks is about 95 to 80 million years old and is geologically well known as the rock of which Half Dome is made.
18. If we superimpose the geologic map onto Yosemite’s topography in Google Earth …
19. … we can see the pink, dashed-pattern of the Tuolumne Intrusive Suite covering the eastern part of the park in the background, while the Western Intrusive Suite (solid colors) covers the foreground.
20. The contact between the two intrusive suites is complex and includes syn-batholithic roof pendants as well as a spectrum of various plutonic rocks genetically related to the emplacement of the Tuolumne Intrusive Suite.
21. If we expand the previous map area several times we can see the vast Tuolumne Intrusive Suite in its entirety, covering almost the entire eastern portion of the park.
22. Shaped something like a horse sitting on its rear, the Tuolumne Intrusive Suite is a world-class example of a “nested” pluton.
23. Like nested bowls, the term implies that progressively smaller plutons are concentrically “stacked” inside larger plutons.
24. As is typically the case for nested plutons, the Tuolumne Intrusive Suite is more mafic on the outside and felsic on the inside. Less common in nested plutons (but certainly not rare) are Tuolumne’s textural differences, which vary from equigranular on the outside, to commonly porphyritic textures on the inside.
25. We can see this pattern in the Half Dome Granodiorite. This piece is near the outside edge of the Tuolumne Intrusive Suite. Notice that all of its crystals are about the same size.
26. In this specimen taken from further inside the suite, notice that some of the crystals are much larger than others and thus the texture is porphyritic.
27. Towards the center of the suite the composition and texture is so much different than the edge, that a different formation name is given. The Cathedral Peak Granodiorite is blatantly porphyritic, with huge alkali feldspar crystals (phenocrysts).
28. Porphyries always indicate two different cooling rates – very slow cooling for the large phenocrysts and more rapid cooling for the finer matrix crystals. As we will see, the models for producing nested plutons not only account for the silica variations seen, but also explain the formation of porphyritic textures.
29. One model works something like this: Since the lower part of the crust is ductile …
30. … plutons, driven by their relative buoyancy, will rise from subduction zones and work their way into the pliable lower crust ...
31. … until they encounter crust equal to their own density.
32. Since this takes place near the bottom of the crust, the cooling rate is very slow, which gives ample time for fractionation of the magma to occur. Like an ice cube freezing, cooling progresses inward such that at some point the outside of the pluton will be solidified while the inside is still magma. Because low silica (mafic) minerals are the first to crystallize from a cooling silicate magma (remember Bowen’s Reaction Series?), the solidified margin of the pluton will be lower in silica than the interior. The magma has now separated, (fractionated) into different components based on silica content. Any crystals growing in the magma at this time will be relatively large because the cooling rate is so slow.
33. Because magma density decreases as silica increases, the residual, silica-rich magma will be buoyed upwards until again it encounters crust equal to its own density.
34. As this magma cools, the faster cooling rate near the surface causes the upper portion of the magma to solidify without fractionation while the lower portion continues to undergo fractionation, producing further silica enrichment in the residual magma.
35. The buoyancy of that silica-enriched magma will cause it to rise as a second pulse of magma forced into the center of the first pulse.
36. When this second batch of magma crystallizes, not only will it have more silica than the first batch, but it is likely to be porphyritic as well. That’s because it began crystallizing at depth where cooling is slow and large crystals form, but it competed crystallization nearer to the surface, where cooling is faster and smaller crystals form.
37. An alternate model for nested plutons relies on different degrees of partial melting to achieve the silica variations, but again could produce the porphyritic textures through crystallization at different depths. Here, a pluton gets stuck at the base of the continental crust …
38. … where it generates a more silica-rich magma by partially melting the base of the continental crust. Silica enrichment buoys the partial melt further upward into the continental crust while the original pluton and residual solids from partial melting become part of the lower crust and upper mantle.
39. If a smaller pluton gets trapped at the base of the crust, …
40. … only a small portion of the crust will melt, which will be only the very most silica-rich minerals. Thus this partial melt will be smaller in volume but greater in silica concentration.
41. Again a nested pluton is produced with a more silica-rich center, but this model may not produce as distinctly porphyritic rocks as the first.
42. The development of the Tuolumne Intrusive Suite probably involved one or both of these mechanisms. Detailed field study of the suite indicates that the first pulse of magma solidified to produce the relatively mafic-rich granodiorite of Kuna Crest. Before this magma had completely solidified …
43. … a surge of fresh magma locally breached the Kuna Crest and solidified as the equigranular phase of the Half Dome Granodiorite. Before this magma completely solidified …
44. … a new pulse of magma intruded and formed the porphyritic phase of the Half Dome Granodiorite.
45. The third surge of magma was followed by the solidification of the Cathedral Peak Granodiorite and emplacement of the Johnson Granite Porphyry.
46. Well if your head hasn’t exploded with all those magma surges, you might think you have a pretty good understanding of magmatic processes now.
47. Well think again!
48. The Tuolumne Intrusive Suite is notorious for boggling geologists with fiendish textures and bizarre structural relationships.
49. There are places where these plutonic rocks take on down-right sedimentary textures.
50. Yet layers can be abruptly juxtaposed against perfectly ordinary crystalline textures.
51. I’ll not explain these …
52. … because I can’t!
53. There even are textures that resemble turbidites!
54. But my favorites are the magma worms!