Geologic, Structural and Geochemical Relationships in Southern Bonelli Park Near the I-57 Landslide Site

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Abstract

Two landslides occurred in 2010 on the south-west hillside of Frank G. Bonelli Park prompting freeway closures that affected thousands of commuters for over two months. Current geologic information reveals a conglomerate unit overlays basaltic flows atop the hillside. My thesis tests a hypothesis that water pressure built up along the contact of the conglomerate and basalt, resulting in translational failure. I conducted an investigation to gain a better 3-dimensional understanding of the area and the factors involved in the landslide.

Six different units were mapped near the slide and illustrated along two cross section lines. Bedding in the conglomerate unit dips southwest; this is the same direction as the slide. Several fractures were observed that probably facilitated percolation of water into the slide mass. The presence of wet clay gouge zones in a couple of places within the conglomerate suggests that adversely dipping fault surfaces may have facilitated slide activation. Unfortunately, details of the freshly exposed slope face were graded over and covered before mapping could be completed. Overall, my pre- and post-slide cross sections suggest a causative geometry in which the porous and conglomerate unit was detached from its stronger, igneous substrate along a gently southwest-dipping daylighted contact.

Fifteen samples from the area were analyzed with X-ray fluorescence. Geochemical analyses indicate that a massive andesite unit (not basalt) found at the base of the slide shows a resemblance to clasts and matrix material found in the conglomerate unit. Most (80%) of the igneous rock units sampled from the study area were andesites; the remainder were dacites.

Introduction

The purpose of this project was to gain a better 3-dimentional understanding of the geologic structure of the south western hillsides in Frank G. Bonelli Regional Park. On February 18 2010, around 8:40 in the morning, a landslide occurred on the west bound 10 to 57 north interchange prompting a closure that lasted 36 days. A little over a month later, a second closure occurred on April 25 due to further debris sliding on to the road. This route is heavily traveled and interrupted thousands of commuters. Heavy January rains probably attributed to the failures along with possible daylighting planes. Field work was conducted in order to find out if there is any further risk of slope failure.

The slope was cut back 2-1 in early March, 2010 in order to lessen the steep road cut created back when the freeways were constructed in the mid 1970's. Other measures were put in place such as benches, concrete drainage, biodegradable netting, K rails, and fast growing vegetation in order to help with slope stability.

Another objective was to compare my findings to the original hypothesis for how the slide first occurred (Nourse, 2010; Poly Post, late Feb. 2010). The basic idea was that water pressure built up between the failed block and an impermeable volcanic layer. Heavy rain - seeped between natural cracks causing possible clay to become slick and swell which caused a reduction in stability.

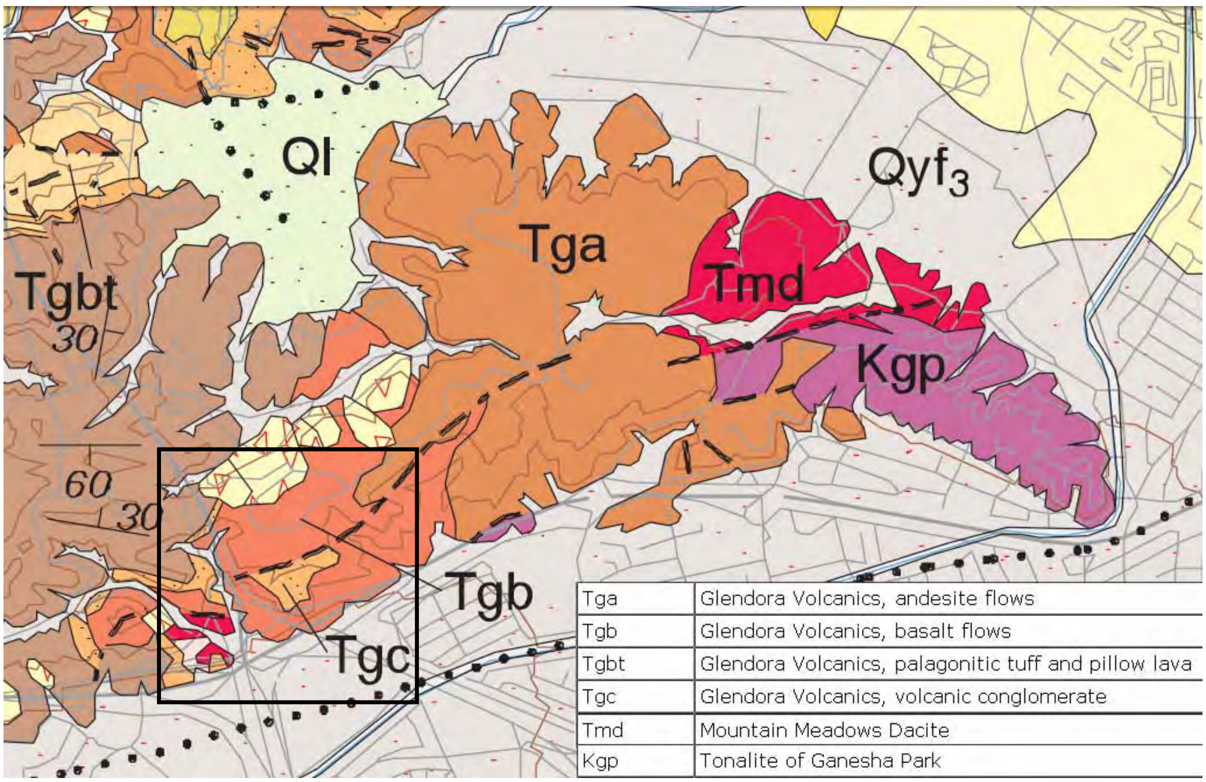
A geologic map was created in greater detail than current publications in order to further understand the geologic setting. This was accomplished by simply walking the region and mapping contacts where possible. Measurements of natural fractures and possible beddings were taken and analyzed using stereonets. Samples were taken, processed, and analyzed with the use of an X-ray spectrometer (XRF). The results from the XRF were then plotted on a total alkalis vs. silica diagram to classify each unit. The results of can then be used to determine if there is any risk of further slope failure.

Site Description and Previous Mapping

The area of interest is located in the south western corner of Frank G. Bonelli Regional County Park in California. It is bound in the southwest by the westbound 10 and 57 north freeway interchange. Access to the base of the failed slope is by the eastbound 10 to the 57 northbound interchange. This was only allowed by special permit through Caltrans personnel on March 9, 2010. Access to the top of the slide and surround hillsides is accomplished by taking the Via Verde exit from the 57 freeway and entering Bonelli Park. The dirt trail is wide enough to allow vehicles but permission is required to gain entry thus I walked to the site.

Figure 2. Pre-slide areal image with field site highlighted (Google Earth 2009).

The rolling hillsides are composed of various lava flows and volcaniclastic strata from the Glendora Volcanics (Shelton 1955). The current USGS San Bernardino Quadrangle (Morton and Miller, 2003) shows the area of interest to comprise of volcanic conglomerate in the higher topographic region surrounded by basalt flows as shown in **Figure 3**. This relationship appears to be reproduced from Shelton's original 1955 map **Figure 4**. The northern most portion is mapped as landslide deposits. Both maps show a northeast trending fault.



Above Figure 3: Cropped image obtained from USGS San Bernardino Quadrangle. Area of interest is highlighted by the black box.

Left Figure 4: Sheltons 1955 Geologic Map

Data

Figure 5 Image of myself taking notes in the field.

Field Work Methods

Periodic trips to the field site were taken between March 9, 2010 and April 26, 2011 in order to gather data on the area. Rock samples were collected to determine the proper lithology of the units with use of XRF. A Garmin etrex Legend HCx handheld GPS unit was used along with a topographic map, obtained from the USGS website, in order to draft a geologic map in the field. The topographic map was overlaying with a grid using OziExplorer in order to make field mapping easier. Both the GPS unit and grid were set to position format UTM UPS datum NAD27 CONUS. A Brunton GEO Pocket Transit compass was used to obtain attitudes on bedding, fractures, and faults. All recordings can be found in the appendix.

The first trip occurred while Caltrans was still grading the slide on March 9, 2010. A personal tour was given by Gustavo Ortega, a Caltrans geologist involved with stabilizing the slide area. During this time it was possible to locate contacts along the exposed surface.

Artesian wells were noted throughout the area appearing in small areas where clay was found outcropping.

Follow up trips were taken between January 14th and April 26 2011. These trips involved mapping contacts, taking attitudes on bedding and fractures, note taking **Figure 5** and sample collecting. Heavy vegetation, such as cactus, along with steep valleys and erosion inhibited mapping in a great deal of areas. The aerial photos below **Figure 6**, obtained from Google Earth, show pre and post slide images.

Figure 6: The image on the left shows what the area looked like on November 19 2009. The image on the right shows the area March 8 2011.

Geologic Map and Cross Sections

The draft geologic map created in the field was used as reference to complete a more presentable digital map. Waypoints taken in the field were plotted on a georeferenced map using OziExplorer **(Figure 7**). The map was then transferred into Adobe illustrator to outline contacts between units and add additional information to the map such as color, patterns, sample locations, beddings, fractures, and faults. The result can be seen in **Figure 8**.

Two cross sections were produced from the geologic map (**Figure 9, 10**). Cross section A-A' trends north-east and crosses the slide slope and power line tower. Cross section B-B' trends north-east as well and shows the geology just east of the slide. Both cross sections were created with the use of the USGS topographic map however; this map base was created in 1966 before the construction of the 57, 71, and 10 freeways and the topography was severely altered in the mid 1970s. Because no newer map bases are published, I used Google Earth functions to get fairly precise locations of the existing freeways. A 1-1 cut was assumed for pre slide conditions and a 1-2 cut for the present post-slide situation.

There was some difficulty in generating the cross sections. The first complication was that the 1966 USGS topographic map was made before the freeways were in place. This meant that the current topography is completely different and the waypoints taken on the slope adjacent to the freeways were not located in the proper elevation. **Figure 9 and 10** show how the waypoints plot on the 1966 topography. Once it was understood that the topography was incorrect the next challenge was creating a cross section that incorporated the various road cuts. Information of the exact slope was unavailable thus it was assumed that the original road cut was 1:1 whereas the current road cut is 1:2 as shown in **Figure 9A and 10A**. The only information that was available was the cut was made 50ft away from the electrical tower. The last obstacle was finding the correct elevation for the freeway transition roads. Google Earth was used to get an estimate on the elevations and widths of each transition road.

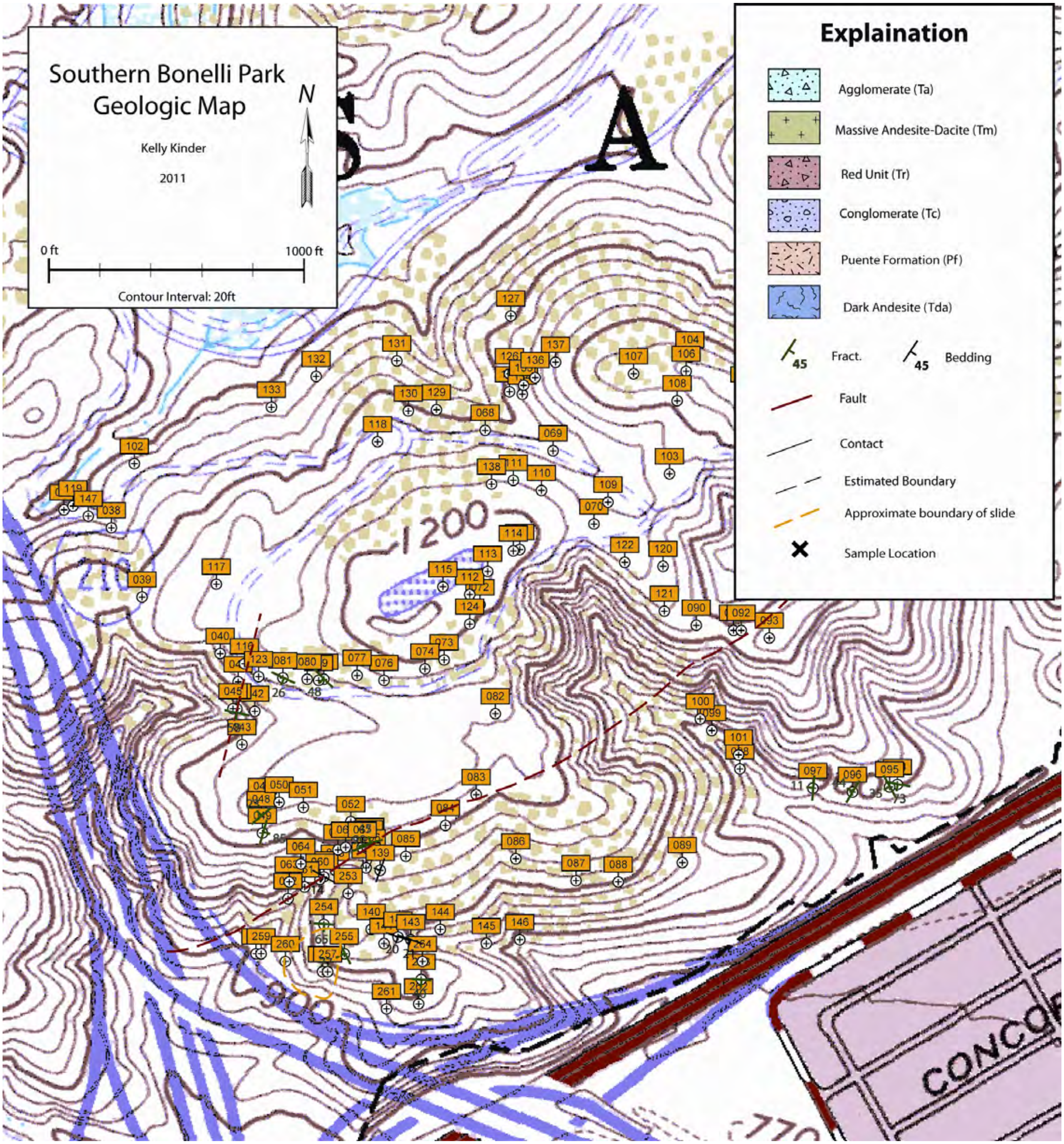


Figure 7: Waypoints plotted on USGS 1966 topographic map.

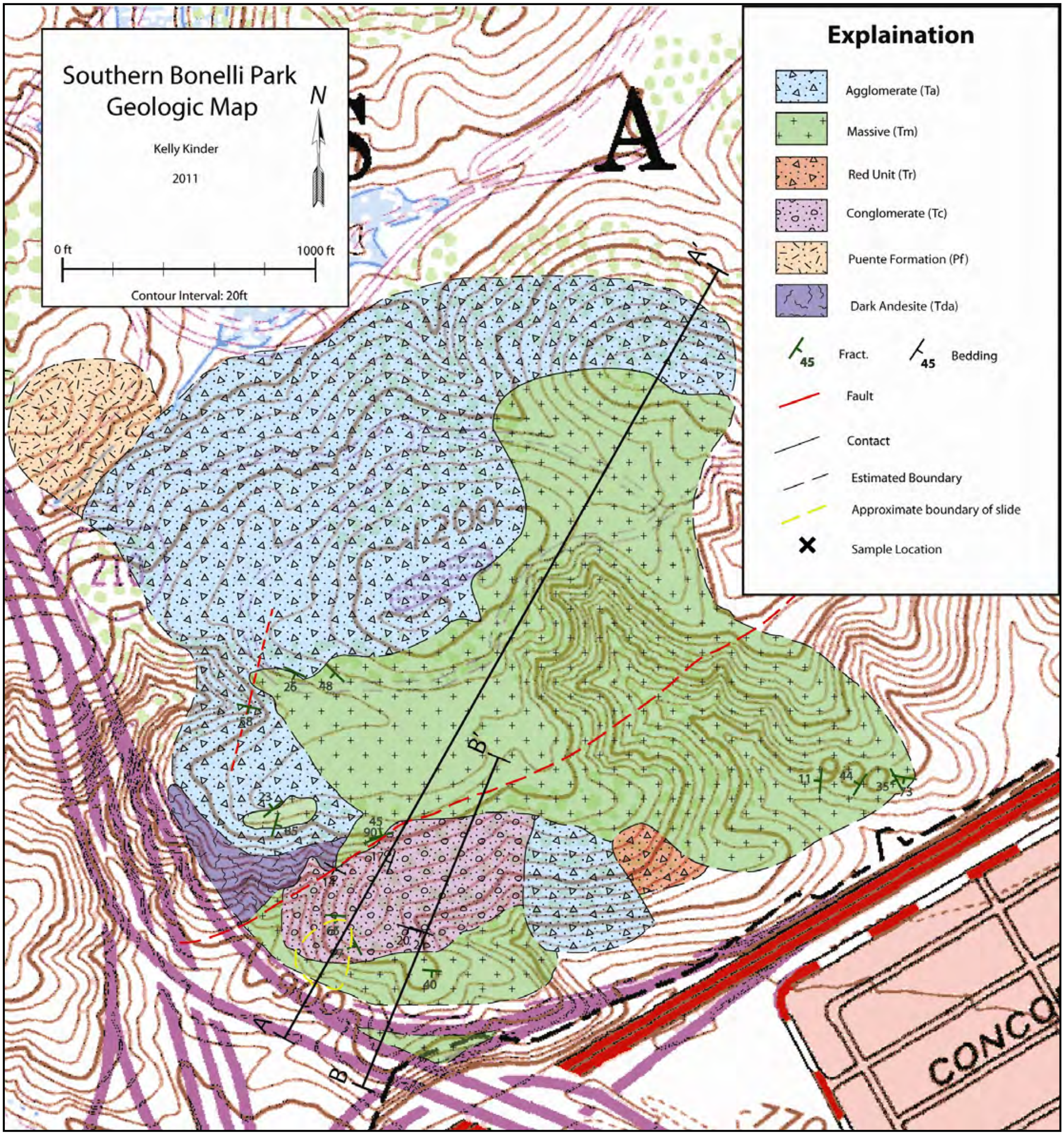


Figure 8 Geologic Map. Some elements have been removed for better visual effect.

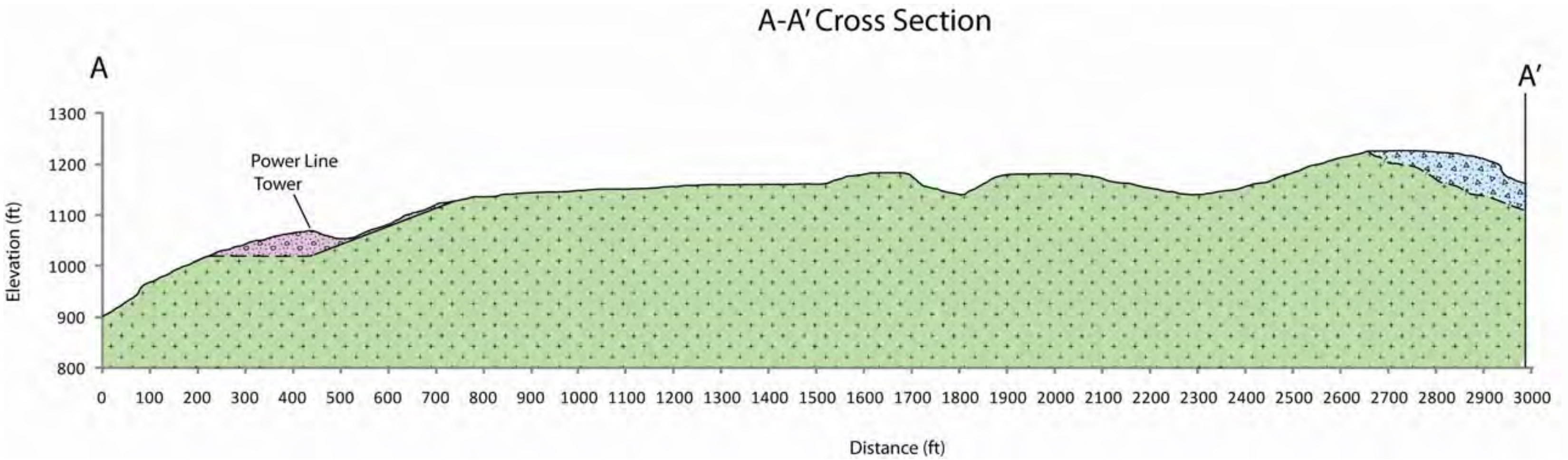


Figure 9: A-A' cross section

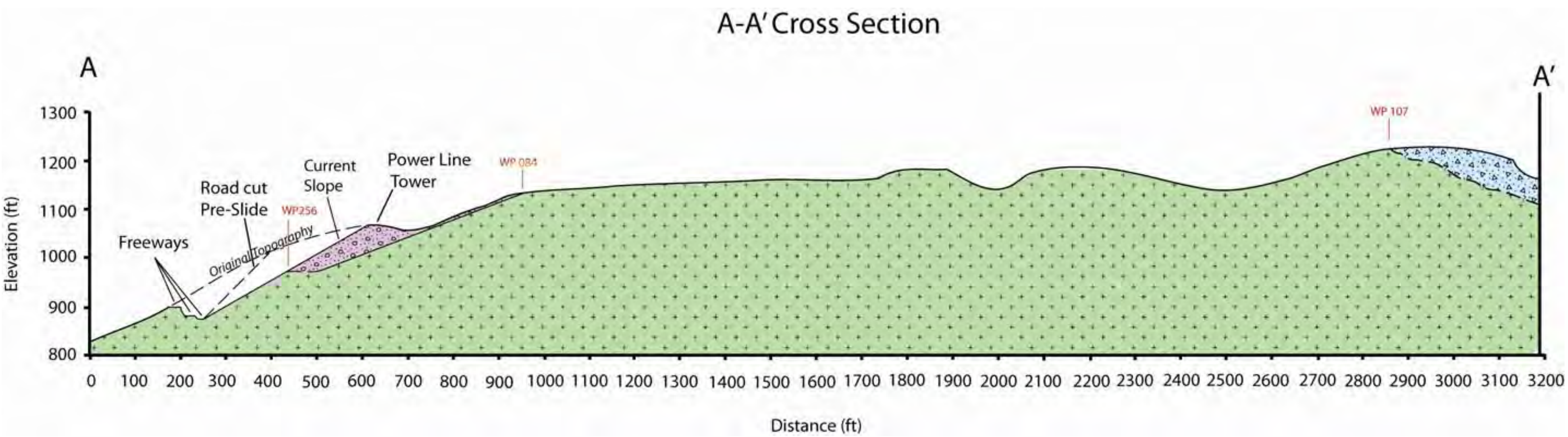


Figure 9A: A-A' cross section with original USGS 1966 topography. NOTE: This cross section is 200 feet less than the figure above.

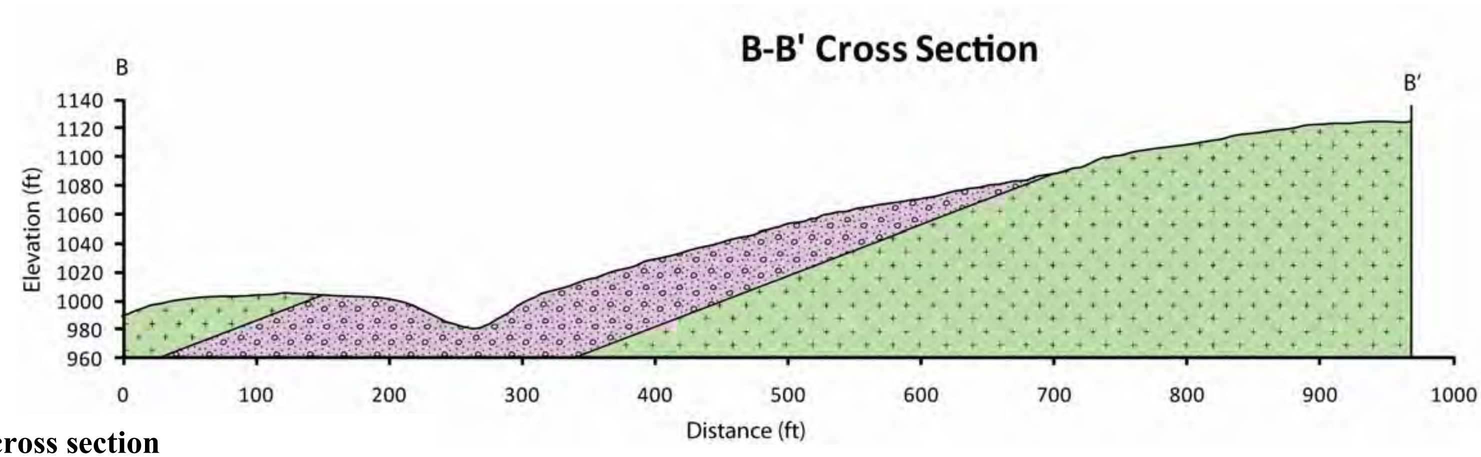


Figure 10: B-B' cross section

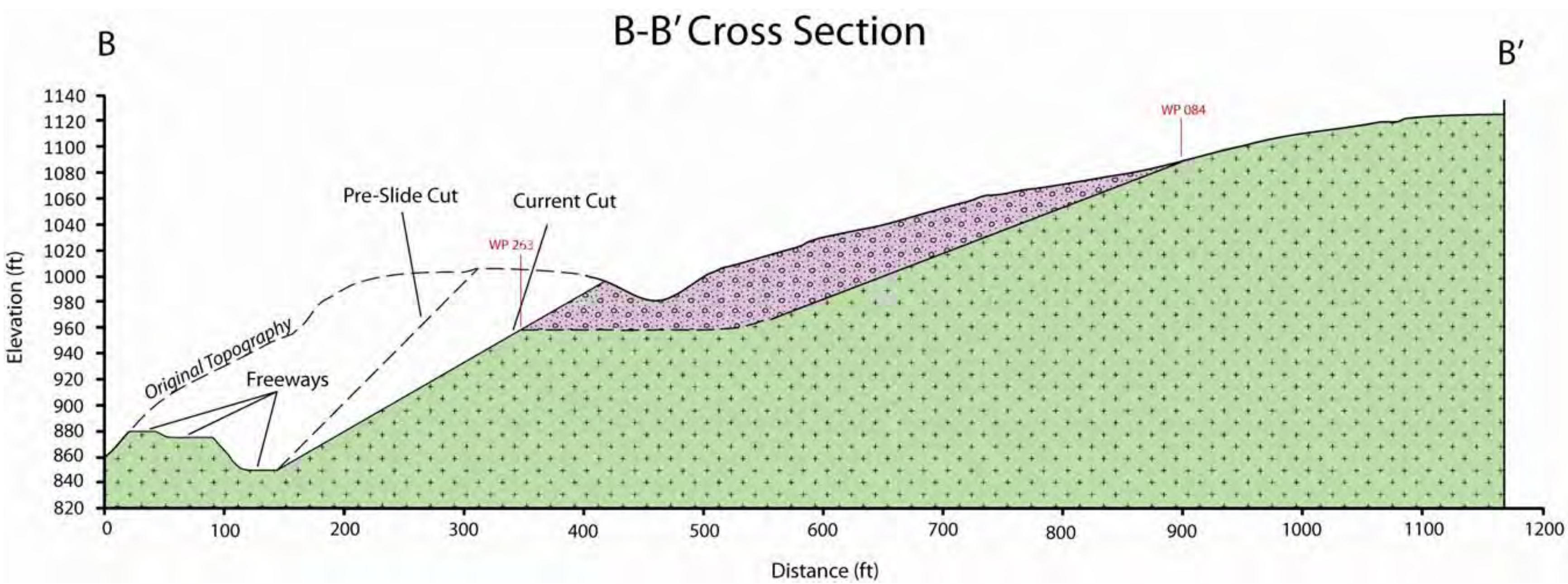
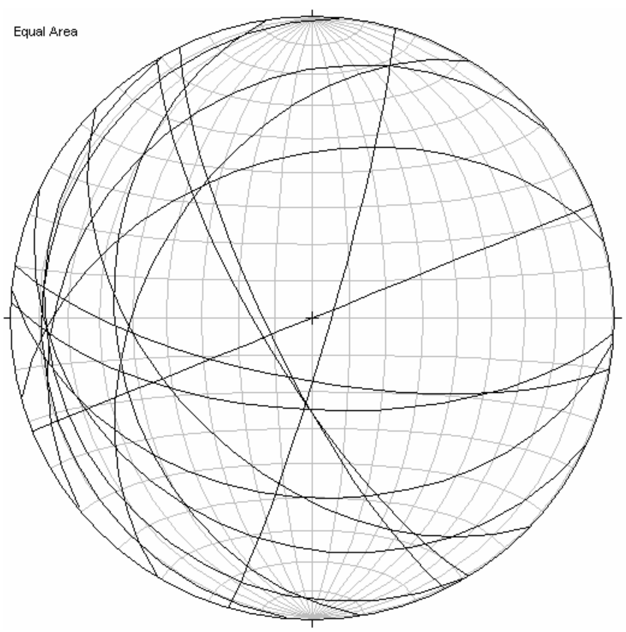


Figure 10A: B-B' cross section with original USGS 1966 topography. NOTE: This cross section is 200 feet less than the figure above.

Stereonet plots

Lower hemisphere equal area stereonet plots were made for natural fractures found in the massive andesite unit (**Figure 11**) and bedding of the conglomerate unit (**Figure 12**). These plots allow for a better 3-dimentional visual representation of structural patterns present in the rocks. Fractures found in the massive andesite-dacite unit reveled no particular pattern whereas the bedding in the conglomerate unit show a very similar strike of 15NW and dip of 11SW.



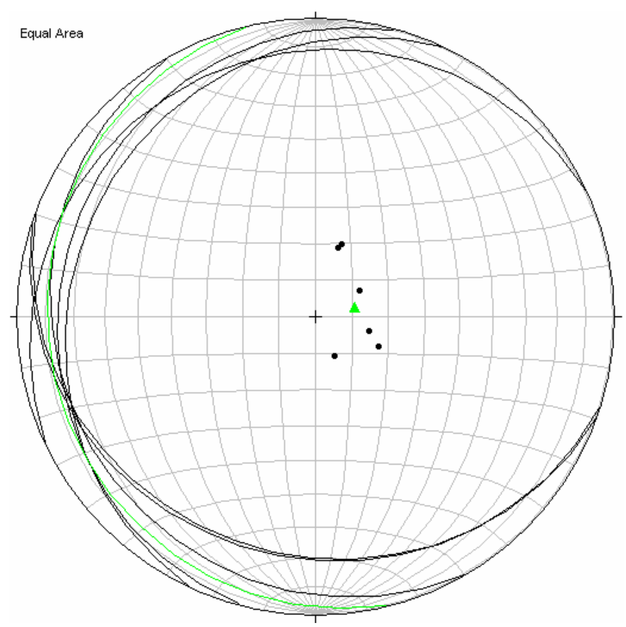


Figure 11: Planes of joint fractures in the massive andesite-dacite unit.

Figure 12: Shows planes to poles of bedding found in the conglomerate unit. Best fit plane and pole are in lime green.

XRF Analysis

Fifteen samples collected in the field were analyzed in the lab with the use of X-ray fluorescence (XRF). The samples gathered by myself were selected based on visual or lithological differences. Other samples were collected by my advisor in outcrops or float when the slide originally occurred. **Figure 14** shows the locations of where each sample was collected.

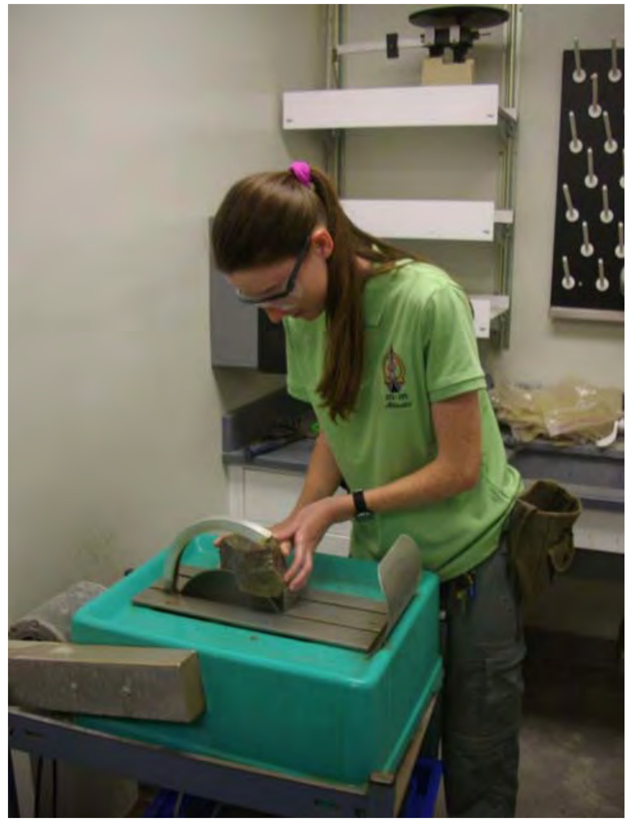


Figure 13: Preparing a sample for XRF analysis.

All samples were prepared by being cut with a hand saw in order to remove weathered material (**Figure 13**). They were left to dry in an oven set to approximately 300°F. The samples were then crushed using a Braun Chipmunk jaw crusher. The smaller pieces were grinded in a SPEX 8000 Mixer/Mill with steel balls until they were able to pass through a 45 sieve (0.355 mm) while the rest were stored for possible further analysis. The powdered sample was mixed with cellulose and held under high pressure in order to create the pellets that are used in the XRF. The results from the XRF were then plotted on a total alkali to silica diagram (TAS). This particular diagram is based upon Le Maitre et al 2002. Full results are tabulated in **Appendix B** where as the TAS diagram can be seen in **Figure 15**.

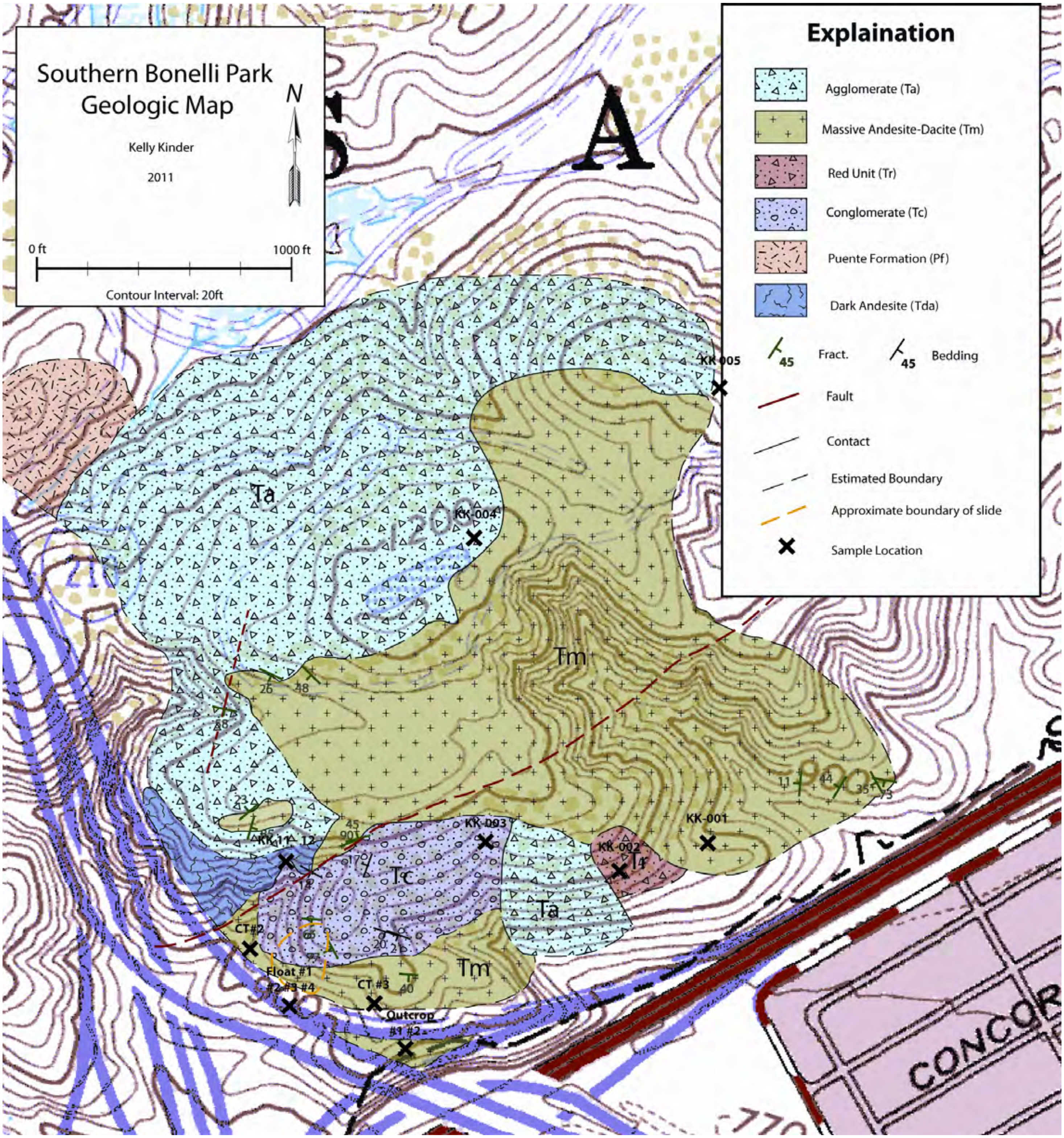


Figure 14: Geologic map with sample locations

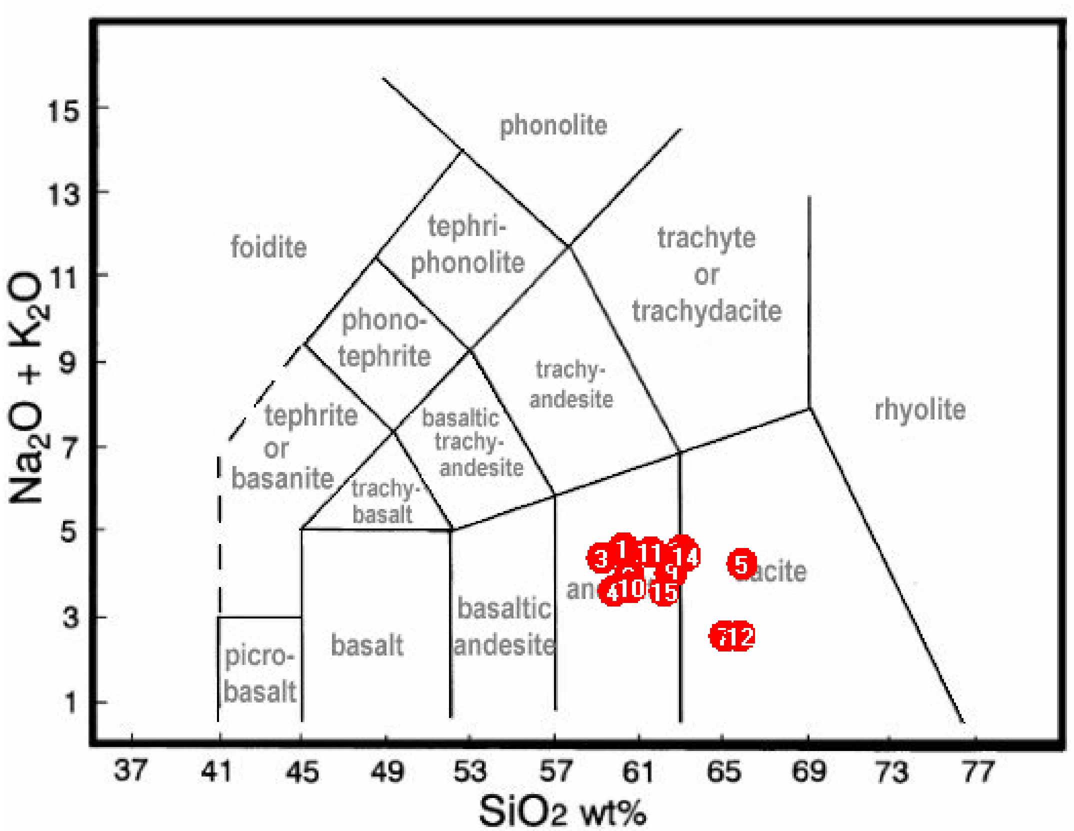


Figure 15: XRF results plotted on a total alkain-silica diagram.

1: KK-011; Possible basalt flow
2: KK-001; Massive
3:KK-005; Possible basalt flow
4: KK-002; Clast in red unit
5: KK-003; Purple clast in conglomerate
6: KK-004; Agglomerate clast
7: FLOAT #1; Conglomerate matrix
8: FLOAT #3
9: FLOAT #4
10: CT #2 FRESH; Massive on slope
11: CT #2 FRACT; Massive on slope
12: CT #3
13:Outcrop #1; Masive on south side of freeways
14: Outcrop #2; Massive on south side of freeways
15: FLOAT #2

Discussion

I was able to show 6 distinct geologic units within my area whereas the current USGS map only shows 2. Shelton mentioned in his 1955 report that he condensed 22 mappable units in the Glendora Volcanics into 8 units with similar characteristics. Shelton's condensed units were needed for the scale of the map he published.

The geologic map created also narrows down the basal contact of the conglomerate unit originally mapped by Shelton (1955). This information allowed for the production of the cross sections which illustrate how the dipping beds found in this unit could have led to the landslide that occurred in 2010.

Stereo nets were created in order to better understand the structural data collected. The initial idea was that fractures in the massive andesite-dacite unit were daylighted to the road resulting in the landslide. The results show no correlation between the natural fractures in the massive andesite-dacite unit. The next idea was to look at bedding found in the conglomerate. There were very few measurable outcrops but the few that were found showed strong preferred orientation: Shallow dip to the southwest. This orientation backs up the original hypothesis that the land mass slid along the basal boundary of the conglomerate.

Previous investigations of the area lump the majority of the flows as basaltic. XRF data shows that all samples collected were andesite, dacite, or borderline andesite-dacite in composition. These results are based on the total alkali to silica diagram created by Le Maitre et al. It might be possible to find another diagram which would result in another nomenclature but I was limited to the program available at the time. Note that the very dark color of the matrix in some samples cannot be used as basis for field classification as basalt. Another result of this data shows that clasts and matrix material in the conglomerate unit have similar composition to a lower massive unit. It is possible that the lower massive was weathered out and incorporated into the conglomerate at a latter time.

Conclusion

Structural data obtained in the hills around southern Bonelli Park in order to understand the relationship between the geology of the region and a landslide that occurred in 2010. The data showed that a layer of south-westerly dipping beds of loosely consolidated conglomerate overlays an impermeable massive andesite-dacite unit. The data supports the original hypothesis that heavy rainfall saturated the slope with water pressure built up along the base of the conglomerate unit. This factor, along with presence of clay noted by the Cal Trans geologist, was the probable cause of the slope failure.

Small slides continue to occur to this day causing concern of another massive landslide. Current slope stability mitigations hopefully will be enough to prevent another massive slide from occurring, given the significant reduction of the slope angle, along with the newly constructed benches.

References

Shelton, J. S. 1955. Glendora Volcanic Rocks, Los Angeles Basin, California. Bulletin of the Geological Society of America 66:45-99.

Nourse, Jonathan A., 2010, *The February 18, 2010 Landslide in Cal Poly Pomona's Back Yard,* Abstract in Provost Symposium on Teaching, California State Polytechnic University, April 16.

Morton, D.M., and Miller, F.K. 2003, Preliminary geologic map of the San Bernardino 30'x60' quadrangle, California: U.S. Geological Survey Open-File Report 03-293.

R. W. Le Maitre, A. Streckeisen, B. Zanettin, M. J. Le Bas, B. Bonin, P. Bateman, G. Bellieni, A. Dudek, S. Efremova, J. Keller, J. Lamere, P. A. Sabine, R. Schmid, H. Sorensen, and A. R. Woolley, 2002, Igneous Rocks: A Classification and Glossary of Terms, Recommendations of the International Union of Geological Sciences, Subcommission of the Systematics of Igneous Rocks. Cambridge University Press.

Appendix A: Table of Field Notes

WP	Zone	Easting	Northing	Lith	Comment	Feature	Strike (Quad)	Strike (Azimuth)	Dip
37	11,	425481	3770390	Puente Conglom	On Road. Sample taken: KK10 Puente Pebble Conglom w/ silt beds. Some cobble and boulder. Clasts: layered volcanics. Quartz				
38	11,	425538	3770366	Agglomerate	Walking next to gate in wash. Went from sed. To ig. Possible fault? Angular and rounded cobbles/ boulders in possible Glendora Volc. Agglomerate: rounded vounded volcanic clast in vol. mat. Volcanic flow that picked up clasts.				
39	11,	425572	3770284	Agglomerate	Porpheritic. Boulder cobble agglomerate w/ porphoritic aphanitic basalt clasts maybe andisite outcrop unit continuously exposed to last wp.				
40	11,	425663	3770213	Agglomerate	Photo taken. Good representation of agglomerate. Still following fire break road. Not very porous.				
41	11,	425683	3770179	Massive Andisite-dacite	Massive blocky weathering light grey dacite/andesite w/ flow banding. Unit is possible overlayn by agglomerate to north-northwest.				
42	11,	425701	3770143	Agglomerate	Back to fragmented agglomerate. On old fire break road.				
43	11,	425685	3770104	Agglomerate	Basaltic agglomerate. Outcrop seems to occur on higher portions of ridge.				
44	11,	425680	3770146	CONT: Agg. - Massive	CONTACT: Agglomerate - Fragmented Rock. In wash. Dominant fracture: S77E/58SW (just below WP) Fault: N13E/ 90 (seperates agglomerate) *PHOTO TAKEN*	Fault	N13E	13	90
45	11,	425675	3770147	Agglomerate	Back in Agglomerate. ~10m thick. At edge of cliff in wash-valley.				
46	11,	425707	3770033	Agglomerate	Basaltic Agglomerate.				
47	11,	425707	3770033	Agglomerate	Basaltic Agglomerate. Covers ridgetop N70W				
48	11,	425705	3770018	CONT: Agg.- Massive	Top of jointed unit. N55E/24NW (KK) S46W/22NW (JN) take avg	Joint	N51E	51	23NW
49	11,	425705	3769998	Massive Andisite-dacite	lower exposure of massive unit. Joint: N16E/85SE	Joint	N16E	16	85SE

50	11,	425727	3770034	CONT: Agg.-Massive	Cont. overlaying agglomerate - underlying fract. Massive. Draw line from WP048				
51	11,	425756	3770027	CONT: Agg.-Massive	Cont. agglomerate exposed to SE. Eastern exposure of massive.				
52	11,	425812	3770008	CONT: Agg.-Massive	Cont. left agg. Now into massive. Autobrecciation. In andisite-dacite massive.				
53	11,	425834	3769982	Massive Andisite-dacite	Outcrop of massive lower unit. Fracture: S75W/45NW	Joint	S75W	75	45NW
54	11,								
55	11,	425833	3769979	Conglomerate	Possibly in down drop side of fault in boulder/cob unit. Round units appear. Rounded Basalt.				
56	11,	425835	3769968	Conglomerate	Andesite clasts. Very Rounded. Tuff? Purple most common unit in Glen. Volc. Ask Mario Caputo about this outcrop. (Ig or Sed?)				
57	11,	425829	3769953	Conglomerate	Tuff rich clasts poor.				
58	11,	425791	3769951	Conglomerate	Andesite-dacite conglomerate				
59	11,	425778	3769944	Conglomerate	Outcrop of andesite-dacite conglomerate. Bedding: S30E/14SW Clasts supported.	Joint	S30E	150	14SW
60	11,	425773	3769942	Conglomerate	Boulder-cobble conglomerate with greenish clay zone.				
61	11,	425754	3769932	Conglomerate	Boulder-cobble conglomerate. Course grained. More Boulders.				
62	11,	425733	3769920	Conglomerate	Boulder-cobble conglomerate with mostly cobbles. Well exposed on both sides of cny. Cont. w/ darker unit ~15m north.				
63	11,	425736	3769940	Basalt Flow Also lower cont of red unit	Basaltic flow unit. (KK11-12). Vesicles. Dark x/ white plag. Phenocryst. Ah-ah flow. This is the lower contact of the red unit and conglom.				
64	11,	425750	3769960	Conglomerate	were on conglom till this point. Walking up center 'hill'				
65	11,	425795	3769976	Massive Andisite-dacite	Massive dacite/Andisite				
66	11,	425805	3769978	Massive Andisite-dacite	Massive dacite/Andisite				
67	11,	425825	3769977	Massive Andisite-dacite	Massive dacite/Andisite Joint: N68E/90	Joint	N68E	68	90

WP		Easting	Northing	Lith	Comment	Feature	Strike (Quad)	Strike (Azimuth)	
68		425987	3770469	massive	Massive outcrop on south-side of road. Goes for ~3m east then goes back to agg.				
69		426067	3770442	massive	Outcrop of massive? Light tan/grey. Tuff? (Sample taken)				
					South of WP22 is agg				
70		426112	3770354	agg	agg				
71		426023	3770325	Basalt	Outcrop of basalt flow. w/ overlying weathered agg. And underlying agg (not weathered) could just be massive. **Same as WP21**				
72		425974	3770262	agg	Clearly back in agg.				
73		425929	3770198	cont	Outcrop of massive. On road cut to north. Agg on road from last WP				
74		425905	3770188	cont	Massive continues to this point only on northern cut. Agg on road.				
75		425881	3770178	cont	massive outcrop again. Goes into road.				
76		425856	3770175		Road shows signs of agg. Massive still continues to north				
77		425824	3770182		Can't tell if clasts in 'massive' outcrop have rounded clasts or are just spalled. Agg still in road.				
78		425785	3770179	cont	CONT agg to east massive to west. (North road cut)	Joint	S46E	134	48SW
79		425779	3770178	cont	CONT of agg - clom in road				
80		425765	3770179	cont	western cont. massive to east agg to west in read and cut.				
81		425736	3770181	Cont	cont in northern road cut. Agg to the east. Massive to the west.	joint (5m west)	S65E	115	26SW
82		425989	3770132		clearly on agg. Unable to determine lith from last WP. ~10m down road see purple clasts… clearly I was wrong.				
83		425962	3770035	agg	outcrop of agg. Road + N-cut				
84		425925	3770000	cont	last sure outcrop of agg. Unsure after; lots of purple.				
85		425876	3769965	conglom	clear outcrop of conglom. Boulder-cobble. Matrix supported. (could go all the way back to WP84)				
86		426007	3769959	cont	Possible contact between conglom - agg. Matrix of agg very soft.				

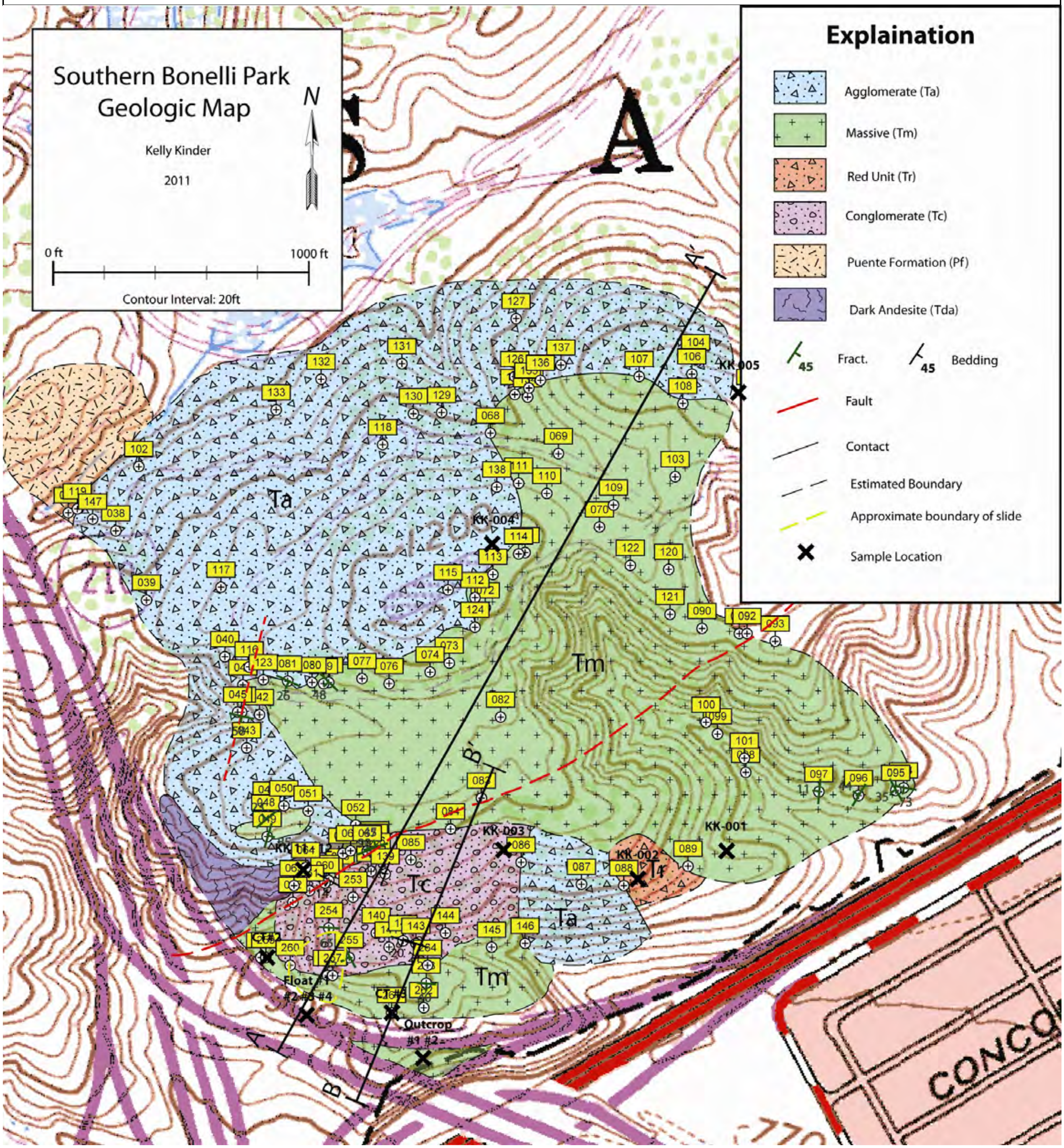
87		426078	3769930		outcrop of ah-ah basalt. North of road. Continues ~10m east. Agglom in underlying. Continues in road				
88		426128	3769927	cont	CONT. agg to the west. Red conglom to the east. Breccia? **SAMPLE TAKEN** reddish matrix as well				
89		426206	3769947	cont	contact of massive further down. Need to locate and mark in road. Still red in cut to north.				
90		426231	3770230	massive	outcrop of massive. Tan outside SF basalt inside				
91		426276	3770222	cont	contact weathered tan massive and dark-purple-red basalt. Flow bands ***SAMPLE TAKEN***				
92		426284	3770221	cont	cont.: Purple massive to west - Agg to the east. Covers hill top. Purple banded basalt clasts found in agg.				
93		426318	3770211	cont	cont: Agg on top of hill (north) tan-massive south				
94		426464	3770031	massive	general fracture trend.	joint	N80W	280	73SW
95		426455	3770029	massive	general fracture trend.	joint	N29W	171	35SW
96		426411	3770024	massive	general fracture trend.	joint	N31E	31	44NW
97		426364	3770030	massive	general fracture trend.	joint	N5E	5	11NW
98		426277	3770056	massive	outcrop of massive in wash				
99		426246	3770103		outcrop of agg on east side of wash. Possible basalt flow as well.				
100		426232	3770118	massive	outcrop of massive. Continues up eastern canyon on NW side				
101		426277	3770073	massive	I think this hillside is all massive				
WP		Easting	Northing	Lith	Comment	Feature	Strike (Quad)	Strike (Azimuth)	Dip
102		425567	3770442	Agg	Agg in road cut to south and ion road. Has been since conglom. 006 is agg. 068 cont of agg to the west, massive to the east.				
103		426204	3770410	Agg	Outcrop of agg or massive. Most likely Agg. Really Large clasts in agg. S.F.B.. On road to north -east water tower. All agg from x-ways.				
104		426234	3770548	Mass	Outcrop of massive on top of hill. Highly weathered.				
105		426297	3770504	Basalt	Possible outcrop of basalt flow. Just east of circular cement slab. PHOTO TAKEN. SAMPLE TAKEN				
					Hillside is massive on eastern path until top where there is an outcrop of a basalt flow.				
106		426228	3770531	CONT	Approximate cont. of massive to east and agg to west on road.				

107		426165	3770531	CONT	cont of agg in west road. Agg overlays massive.				
108		426216	3770496	Massive	Outcrop of massive in road and road cut.				
					Going to stick with massive as the underlying main rock unit to point 103. Assuming rounded cobbles came from above.				
109		426130	3770379	agg	Outcrop of agg on road to pond.				
110		426051	3770395	mass	Outcrop of massive. Continues up hill. Down hill is questionable.				
111		426018	3770408	CONT	cont of massive to east agg to north				
					Agg covers hilltop around lake				
112		425961	3770274	mass	outcrop of massive				
113		425985	3770300	massive	outcrop of massive				
114		426016	3770324	massive	outcrop of massive. WP071 is massive				
115		425930	3770284	CONT	aprox. Contact of agg to the north west and massive to the south.				
116		425690	3770201	mass/agg	Massive in cut to east. Agg in road. Agg in cut to north along road now.				
117		425661	3770295	agg	agg continues in road and up hillside				
118		425858	3770459	agg	outcrop of agg in road. As we walk back all agg.				
119		425492	3770394	cont	cont of agg and clom				
120		426193	3770301	massive	pile of S.F.B.. Just a pile of broken fragment. Massive.				
121		426194	3770246	massive	outcrop of massive. Light tan. S.F.B light in color				
122		426148	3770306	massive	outcrop of massive. Its just weathered strangely.				
123		425707	3770185	CONT	cont. massive to east. Agg to west. On actual road above fire road.				
124		425961	3770240	CONT	cont agg in road to west. Massive in all other directions in crotch of road.				
125		426017	3770513	agg	outcrop of basalt flow/ agg				
126		426018	3770535	agg	still in outcrop of agg/basalt flow				
127		426021	3770603	agg	outcrop of agg possibly overlain by basalt flow.				
128					outcrop of basalt flow.				
129		425929	3770495	agg	outcrop of agg / basalt flow. Continues south up hill.				

130		425896	3770495	agg	outcrop of agg / basalt flow.				
131		425883	3770555	massive	outcrop of massive in old road cut to south. Most likely overlain by agg. Has been agg since last wp.				
132		425787	3770539	agg	outcrop of agg.				
WP	Zone	Easting	Northing	Lith	Comment	Feature	Strike (Quad)	Strike (Azimuth)	Dip
253	11,	425827	3769925	Conglomerate	13' North East of tower: Outcrop of Conglomerate				
254	11,	425775	3769987	Conglomerate	Striated fracture surface silty interval in conglomerate. ~4m NE of top bench. Seems to be spring close to cont.	Bedding?	S87E	93	65SW
255	11,	425799	3769853	N/A	Edge of south Top Bench. Moved to Second Bench by NW Drainage. - Smelled… Darker clay enriched soil. Vegetation: cactus.	Fracture	N31W	149	76SW
						Fracture	N26W	154	78SW
256	11,	425773	3769831	Conglomerate	Approaching East end second bench. Course cobble conglomerate above. 37' thick (need to take into account slope angle) *Drawing in notes*				
259	11,	425702	3769854	Basaltic Andisite	CT2 Sample collected (Basaltic) andesite. One fresh one frac.				
260	11,	425729	3769845	Cont.	Bottom of conglom. Top of Basalt-andesite.				
261	11,	425848	3769784	Rhyolite	On south east slope (NOT landslide) Sample taken CT3: Rhyolite w/ angular frag. Of pumice. Felsic. Volcanic breccia. Lots of limonite fract. Lots of clay in fract.				
262	11,	425987	3769790		SE bottom cut. Top of bleached white zone with strongly slicke basalt. Above lays a yellow orange weathered breccia.				
263	11,	425891	3769819		Felsic volcanic. Close to old scarp. Dom. Frac. Surface. ~1/2 way up the slope.	Fracture	N85W	275	40SW
					Rhyolite flow w/ fragments. Maybe dacite. Feldspar weathers to clay.				
264	11,	425???	3769840		cobble conglomerate overlaying rhyolite/dacite unit				
WP	Zone	Easting	Northing	Lith	Comment	Feature	Strike (Quad)	Strike (Azimuth)	Dip
133	11,	425732	3770504	agg	outcrop of agg				
134	11,	426032	3770509	agg	outcrop of agg to north. Cactus prevents further exploration				
135	11,	426033	3770521	agg	outcrop of agg *SAMPLE TAKEN*				
136	11,	426047	3770529	massive	outcrop of massive surrounded by cactus				

137	11,	426073	3770547		it's a sign! WS				
138	11,	425993	3770404	agg	outcrop of agg in road				
139	11,	425845	3769949	conglom	outcrop of conglom. SAMPLE SPOT	bedding	N25E		19NW
							N15E		15NW
140	11,	425832	3769880	conglom	outcrop of matrix supported conglom				
141	11,	425846	3769862	conglom	outcrop of matrix supported conglom				
142	11,	425864	3769869	conglom	sandy pebbly conglomerate zone *PHOTOS TAKEN*	bedding	N72W		20SW
143	11,	425879	3769866	conglom	sandy pebbly conglomerate zone. Good bedding.	bedding	S70E		21SW
144	11,	425914	3769876	conglom	possibly transitioning from sed conglom to dacite conglom.				
145	11,	425969	3769858	massive	outcrop of possibly massive. Has some rounded clasts.				
146	11,	426009	3769861		well into massive. All covered. Many clasts in colluviums.				
147	11,	425511	3770380	conglom	on real conglom.	bedding		245	12NW

Appendix B Way Point Locations and Sample Locations plotted on geologic map



Appendix C: XRF Results

Type:	Routine
Application:	USGS STANDARDS
Sample:	KK-011
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	17.454
CaO	%	8.059
Fe2O3	%	6.255
K2O	%	0.707
MgO	%	1.956
MnO	%	0.083
Na2O	%	3.908
P2O5	%	0.230
SiO2	%	60.238
TiO2	%	1.110

(Table 1) Sample KK-011 Results

Type:	Routine
Application:	USGS STANDARDS
Sample:	KK-005
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	18.827
CaO	%	7.373
Fe2O3	%	6.893
K2O	%	0.576
MgO	%	1.856
MnO	%	0.086
Na2O	%	3.840
P2O5	%	0.228
SiO2	%	59.262
TiO2	%	1.060

(Table 2) Sample KK-005 Results

Type:	Routine
Application:	USGS STANDARDS
Sample:	KK-001
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	20.438
CaO	%	6.018
Fe2O3	%	4.339
K2O	%	0.911
MgO	%	0.379
MnO	%	-0.006
Na2O	%	3.540
P2O5	%	0.314
SiO2	%	62.806
TiO2	%	1.261

(Table 3) Sample KK-001 Results

XRF Results continued

Type:	Routine
Application:	USGS STANDARDS
Sample:	KK-002
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	16.676
CaO	%	7.674
Fe2O3	%	7.844
K2O	%	0.653
MgO	%	2.807
MnO	%	0.072
Na2O	%	2.964
P2O5	%	0.383
SiO2	%	59.820
TiO2	%	1.108

(Table 4) Sample KK-002 Results

Type:	Routine
Application:	USGS STANDARDS
Sample:	KK-003
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	18.795
CaO	%	5.163
Fe2O3	%	4.330
K2O	%	0.730
MgO	%	0.636
MnO	%	0.003
Na2O	%	3.550
P2O5	%	0.120
SiO2	%	65.847
TiO2	%	0.825

(Table 5) Sample KK-003 Results

Type:	Routine
Application:	USGS STANDARDS
Sample:	KK-004
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	18.121
CaO	%	6.911
Fe2O3	%	7.035
K2O	%	0.558
MgO	%	2.037
MnO	%	0.075
Na2O	%	3.450
P2O5	%	0.171
SiO2	%	60.530
TiO2	%	1.114

(Table 6) Sample KK-004 Results

XRF Results continued

Type:	Routine
Application:	USGS STANDARDS
Sample:	Float #1
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	16.649
CaO	%	5.490
Fe2O3	%	7.133
K2O	%	0.600
MgO	%	1.911
MnO	%	-0.004
Na2O	%	1.966
P2O5	%	0.227
SiO2	%	65.072
TiO2	%	0.957

(Table 7) Sample Float #1 Results

Type:	Routine
Application:	USGS STANDARDS
Sample:	Float #2
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	20.081
CaO	%	5.597
Fe2O3	%	5.610
K2O	%	0.426
MgO	%	1.354
MnO	%	0.025
Na2O	%	3.196
P2O5	%	0.264
SiO2	%	62.236
TiO2	%	1.210

(Table 8) Sample Float #2 Results

Type:	Routine
Application:	USGS STANDARDS
Sample:	Float #3
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	20.221
CaO	%	5.395
Fe2O3	%	5.908
K2O	%	0.891
MgO	%	0.496
MnO	%	-0.006
Na2O	%	3.160
P2O5	%	0.384
SiO2	%	62.509
TiO2	%	1.041

(Table 9) Sample Float #3 Results

XRF Results continued

Type:	Routine USGS
Application:	STANDARDS
Sample:	Float #4
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	20.899
CaO	%	5.433
Fe2O3	%	4.899
K2O	%	0.947
MgO	%	0.412
MnO	%	-0.009
Na2O	%	3.157
P2O5	%	0.437
SiO2	%	62.594
TiO2	%	1.231

(Table 10) Sample Float #4 Results

Type:	Routine USGS
Application:	STANDARDS
Sample:	CT #2 Fresh
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	17.627
CaO	%	7.306
Fe2O3	%	6.787
K2O	%	0.457
MgO	%	2.354
MnO	%	0.057
Na2O	%	3.278
P2O5	%	0.362
SiO2	%	60.586
TiO2	%	1.187

(Table 11) Sample CT #2 Fresh Results

Type:	Routine USGS
Application:	STANDARDS
Sample:	CT #2 Fractured
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	18.286
CaO	%	6.625
Fe2O3	%	5.449
K2O	%	0.487
MgO	%	1.937
MnO	%	0.042
Na2O	%	4.058
P2O5	%	0.395
SiO2	%	61.579
TiO2	%	1.141

(Table 12) Sample CT #2 Fractured Results

XRF Results continued

Type:	Routine USGS
Application:	STANDARDS
Sample:	CT #3
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	15.779
CaO	%	5.278
Fe2O3	%	5.996
K2O	%	0.859
MgO	%	3.299
MnO	%	0.018
Na2O	%	1.725
P2O5	%	0.272
SiO2	%	65.837
TiO2	%	0.938

(Table 13) Sample CT #3 Results

Type:	Routine USGS
Application:	STANDARDS
Sample:	Outcrop #1
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	18.132
CaO	%	6.618
Fe2O3	%	5.611
K2O	%	0.917
MgO	%	0.642
MnO	%	0.007
Na2O	%	3.657
P2O5	%	0.317
SiO2	%	63.041
TiO2	%	1.059

(Table 14) Sample Outcrop #1 Results

Type:	Routine USGS
Application:	STANDARDS
Sample:	Outcrop #2
Init weight:	6 g
Flux weight:	1.2 g
Final weight:	7.2 g
Norm.factor:	1.1754

Compound	Unit	Value
Al2O3	%	16.921
CaO	%	7.189
Fe2O3	%	6.096
K2O	%	0.941
MgO	%	0.756
MnO	%	-0.001
Na2O	%	3.517
P2O5	%	0.328
SiO2	%	63.185
TiO2	%	1.067

(Table 15) Sample Outcrop #2 Results