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Sources of archaeological dacite in northern New Mexico

M. Steven Shackley

Geoarchaeological XRF Laboratory, Department of Anthropology, University of California, Berkeley, CA 94720-3710, USA

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ABSTRACT

For years archaeologists in New Mexico, particularly in the northern Rio Grande region have noticed a very fine-grained what appeared to be mafic or basalt raw material source in late Paleoindian and Archaic contexts in northern New Mexico and southern Colorado. Indeed, a number of Folsom, Cody, Plainview, and Archaic bifaces are produced from this material. It appeared that there were at least two possible very fine-grained volcanics that could be the sources for these raw materials – San Antonio Mountain in far northern New Mexico, in the Taos Plateau Volcanic Field, and Cerros del Rio, on the east side of Bandelier National Monument right above the Rio Grande. After reconnaissance collections at the two probable sources, the short story is that the vast majority of "basalt" artifacts were indeed produced from one of these sources, but they are petrologically dacite and silicic volcanic rocks. An additional dacite source, called here the "Newman Dome", also in the Taos Plateau Volcanic Field was discovered in the 1980s, but remained mainly discussed in the gray literature by CRM archaeologists. Examination of various Paleoindian and Archaic collections from the northern and middle Rio Grande indicates a strong preference for this silicic rock for the production of chipped stone tools, and in concert with obsidian source provenance studies has increased our ability to reconstruct procurement and range in these preceramic periods. These high-alkali dacite sources are easily discriminated with their trace element compositions, and based on this study, procurement seems to be dominantly restricted to these three sources in the region. Here I discuss the petrology, geochemistry, and some of the archaeological issues of these sources and their utility in the Southwest archaeological endeavor in an effort to bring these important prehistoric raw materials into the published realm.

1. Introduction

Those of us working in the northern Rio Grande Valley of New Mexico and southern Colorado have noticed a very fine-grained what appeared to be mafic or often called "basalt" raw material source in late Paleoindian and early Archaic contexts in the region (Boyer, 2010; Bryan and Butler, 1940; Seaman, 1983; Shackley, 2005a; Vierra et al., 2005; Vierra, 2010)[1]. Pegi Jodry (Smithsonian Institution) and Brad Vierra (then at Los Alamos National Laboratory) had been working with private collectors, CRM collections, and others on Paleoindian and Early Archaic projectile points in southern Colorado and northern and central New Mexico, and suspected that there were at least two very fine-grained volcanics that could be the sources for these raw materials – San Antonio Mountain in far northern New Mexico, in the Taos Plateau Volcanic Field, and Cerros del Rio, on the east side of Bandelier National Monument right above the river (Vierra et al., 2005; fig. 1 here). The artifacts and source samples collected from these two sources were sent to Berkeley to determine provenance (Shackley, 2005a). However, compositional analyses and a thin section study indicated that these two "basalt" sources are not basalt at all. The San Antonio Mountain volcanics have been called basalt by some archaeologists for years, despite Lipman and Mehnert's early analysis indicating a "rhyodacite" and Newman and Nielsen's EDXRF study indicating the same (Lipman and Mehnert, 1979; Newman and Neilsen, 1987). My initial hand sample examination including test knapping suggested to me that this was more silicic than basalt or even andesite (Shackley, 2005a). Through compositional analyses, a reexamination of these three sources, as well as optical petrography, it is clear that these three volcanic rocks are

E-mail address: shackley@berkeley.edu.

[1] There are many "gray" literature references to intermediate and silicic stone raw materials on the Taos Plateau (regional presented papers, CRM documents, etc.), and while an attempt was made to reference these, not all could be found. As a former CRM archaeologist, my apologies to the local archaeologist's understanding of andesite and dacite raw materials. This, of course, is an example of the constant tension between private sector and academic archaeology. So little gray literature is available outside the contract archaeology office or sometimes museum archives, that it is difficult to track down. However the vast majority of the Late Paleoindian and Archaic material referenced here from sites from northern to central New Mexico are from these three sources.

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dacite and were popular sources of tool stone during the preceramic period in the northern Southwest. The initial archaeological studies by Shackley (2005a, 2010), Vierra et al. (2005), and Vierra (2010)suggest that provenance analysis of dacite artifacts along with obsidian artifacts from these early contexts in the northern Southwest exhibit great utility in elucidating procurement ranges occupied during Paleoindian and Archaic times (Shackley, 2005b; see also Boyer, 2010). Much of this archaeological work is being published elsewhere (i.e. Vierra, 2010), but the geochemical and geoprospection data are offered here as a basis for further archaeological study, and a stimulus to bring some of the gray literature studies on these sources into the published realm.

Parenthetically, there has been some gray literature examination of some of the intermediate rock sources on the Plateau, such as Seaman's (1983) look at the andesite shield Guadalupe Mountain, and Boyer's (2001) excellent discussion of stone quarries on the Plateau, but no recent comprehensive geological and compositional analysis of these sources. Generally most discussions have been in contract archaeology reports (see also Seaman and Chapman, 1993).

2. Geoarchaeological setting: Taos Plateau and Cerros del Rio volcanic fields

A short outline of the geological setting and archaeological evidence for these three dacite sources is useful for understanding their distribution and location in space. All of these dacite sources are relatively recent Plio-Pleistocene eruptive events and exhibit large nodules, some up to a meter in largest dimension, one reason they were likely popular in these early time periods when large nodule sizes are necessary for the production of dart points.

2.1. San Antonio Mountain and the Newman Dome in the Taos Plateau Volcanic Field

Initially defined by Lipman and Mehnert in 1979, the Taos Plateau Volcanic Field is a 30 by 50 km cluster of over 35 central vent volcanic shields and cones, ranging from basalt to rhyolite most erupted between 4.5 and 2.0 Ma (1979, 289; see fig. 1 here). Tholeitic shields occur in the center with the dacite volcanoes like San Antonio Mountain and the Newman Dome on the edges, and rhyolite centers in the central part of the field, in this case the No Agua Peaks' high silica perlite and obsidian source (Newman and Neilsen, 1987; Glascock et al., 1999; Shackley, 2005b; fig. 1 here).

2.1.1. San Antonio Mountain

San Antonio Mountain is a late Pliocene[2] dacite shield volcano that dominates the western Taos Plateau (Eppler, 1976; Lipman and Mehnert, 1979; fig. 1 here). There are other shield volcanoes that may be volumetrically similar, but San Antonio Mountain as a large dacite volcano is imposing in its character that can be seen in satellite images (Fig. 1). Eppler's (1976) Master's thesis on the mountain is the best single geological study of the volcanic feature. A solitary potassium–argon date of San Antonio Mountain rock is reported as 3.12 $\pm$ 0.17 by Lipman and Mehnert (1979, 295) (Fig. 1).

In 1940 Kirk Bryan and Arthur Butler characterized the San Antonio Mountain dacite as a "glassy andesite" based on an interesting early modal analysis derived from optical microscopy and the identification of mineral composition (1940, 28–29). Typically for Bryan's care in his early geoarchaeology, he warns that: "Artifacts made from this rock may be confused with those made from the hypersthene andesite unless care is used in identifying the rock." This advice is certainly easier to heed with today's modern instrumentation and compositional analysis - the basis for this study.

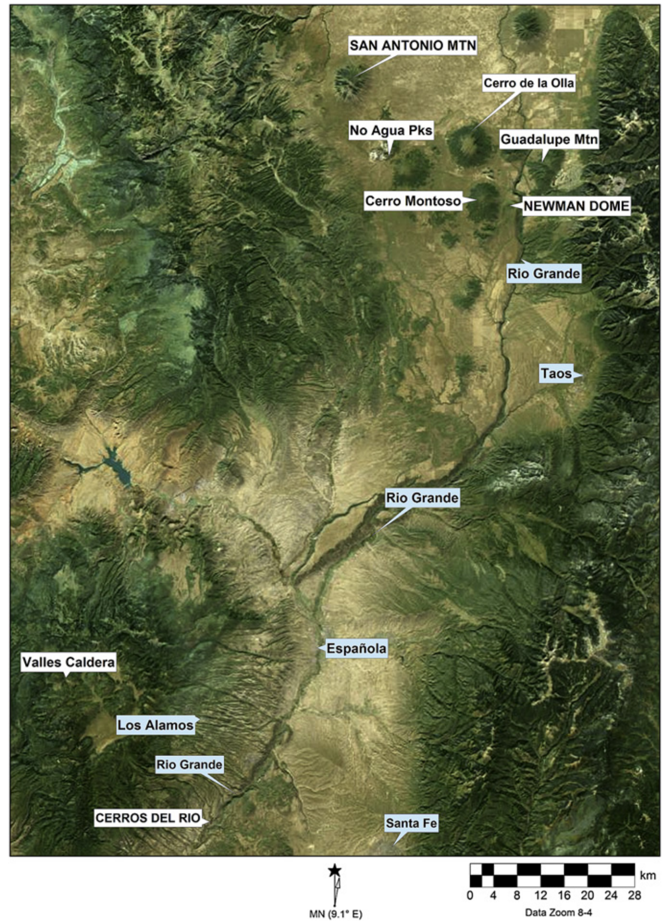

Fig. 1. Grayscale digital elevation model showing the three dacite source locations in northern New Mexico. Source locations in capitals, geographic and municipal features in lower case. The large andesite shields on the Taos Plateau Volcanic Field are readily visible in the upper right corner between the dacite San Antonio Mountain and the Newman Dome just east of the andesite Cerro Montoso.

The event produced a very large volume of dark gray dacite with very sparse phenocrysts of alkali feldspar in a glassy matrix (Fig. 2a). Most nodules are aphyric and glassy. Nodules collected from the southern, western, and eastern slopes are generally angular to globular to lens shaped, some up to 50 cm in largest dimension, but most 20–30 cm, certainly large enough to produce dart preforms. The rocks occur in lenses of very high density throughout the regolith, but the knapping quality of the stone varies significantly. While some large flakes, probably prehistoric, were noted on the surface, no biface preforms were recorded in four separate visits to the volcano. Knapping quality is also variable, but when an aphyric glassy nodule was obtained, it was relatively easy to produce large hard and soft hammer biface preforms in 10–30 min. My experience with nodules of San Antonio Mountain dacite suggests that at least 50% of the nodules collected could be used to produce adequate bifaces.

2.1.2. Newman Dome

I have chosen to use the name "Newman Dome" since the volcanic feature has not been named (Lipman and Mehnert's "unnamed rhyodacite volcano") and for the discovery of the value of this raw material by Jay Newman in the 1980s (Lipman and Mehnert, 1979, 305; Newman and Nielsen, 1987, 263). This dome

[2] As of June 2009, the Executive Committee of the IUGS has formally lowered the base of the Pleistocene Series/Epoch to 2.58 Ma (Gibbard et al., 2009). This new base for the Pleistocene is used for reference here.

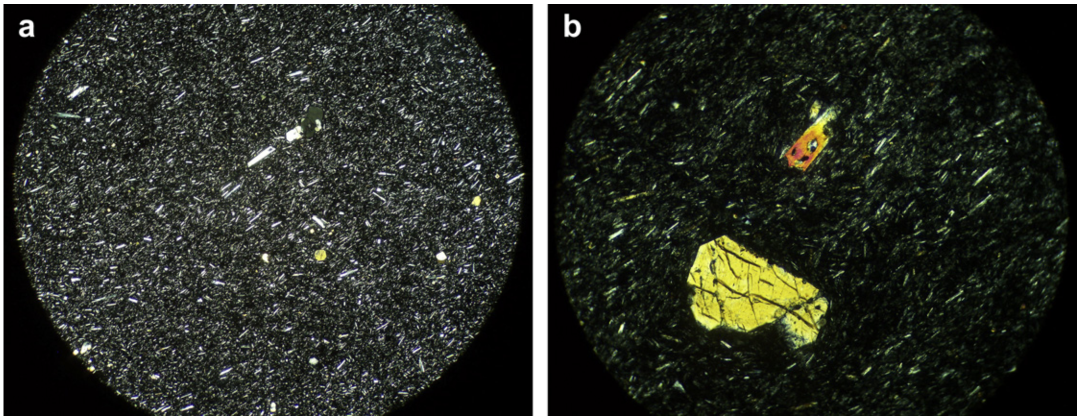

Fig. 2. Thin sections of San Antonio Mountain (a) and Cerros del Rio (b). Note the parallel to sub-parallel orientation of the plagioclase laths and the pyroxenes in the Cerros del Rio section. 100X.

complex has also been called "Cerro Sin Nombre" by Boyer and Moore (2001). Unlike San Antonio Mountain, this appears to be a relatively small dacite dome complex just east of the andesite Cerro Montoso and just west of the Rio Grande gorge, trending approximately 2.5 km along a north–south axis and about 1.5 km east–west at the largest point. It was identified by Jay Newman in the northern New Mexico late period Pot Creek Pueblo assemblage and actually dominated the dacite artifacts at the site (Newman and Nielsen, 1987). San Antonio Mountain and some of the other Taos Plateau andesite sources were present, but in smaller proportions. Jay Newman's discovery of the use of this dacite in late period sites and the provenance study that resulted was virtually the only compositional dacite study in late period sites in New Mexico at the time in the published literature (but see Dello-Russo, 2004 for a similar study on silicified rhyolite in southern New Mexico).

After field work at the dome complex in 2010, it became apparent why this source was so dominant at Pot Creek Pueblo. Of the three major dacite sources detected in early sites in New Mexico and Colorado, the Newman Dome dacite is the finest raw material of the three. It is nearly completely aphyric and sanidine phenocrysts are very small and rare. It is very glassy, and while all the sources exhibit large nodules, the Newman Dome material often comes in large flat boulders some nearly 1 m in largest dimension. This is certainly one reason why it was so popular in prehistory. Its knapping quality is similar to some chert materials, less brittle than obsidian, but certainly more brittle than other volcanic rocks. While the Cerros del Rio dacite discussed below is a nearly equal raw material, the Newman Dome dacite exhibits a much higher volume at the source. Cerros del Rio dacite is restricted to the relatively small chill zone.

The hand sample character of the Newman Dome dacite is very similar to San Antonio Mountain. Indeed, in hand sample it is very difficult to distinguish the three sources (Fig. 3). Some of the Newman Dome material, however, is so fine grained it borders on a glassy or vitreous fabric. Flakes are common over the entire surface surveyed, at times up to 50/m^2 and six broken biface preforms were located in the same area. Much of the debitage and most of the preforms exhibited considerable patination, appearing as a dull brown wash also noted by Bryan and Butler (1940). This source was popular in prehistory.

2.2. Cerros del Rio chill zone

Unlike the Taos Plateau Volcanic Field dacite volcanoes, the dacite in the Cerros del Rio Volcanic Field is a dome remnant or chill zone beneath a later basalt flow. The Cerros del Rio Volcanic Field is dominated by basalt through central vent fissure flows (Thompson et al., 2001). Unlike the Taos field, the compositional variation in Cerros del Rio is a result of pockets of evolved magma and in the case of the dacite, remelted crustal material (Thompson et al., 2001).

The following is from a field report by Dave Broxton, a geologist at Los Alamos National Laboratory (Broxton et al., 2005), slightly edited here:

Fig. 3. Early and Middle Archaic obsidian and dacite points from surface contexts at Valles Caldera, northern New Mexico. All obsidian points produced from Valles Rhyolite (Cerro del Medio). The two dacite points illustrate the similarity in megascopic character and patination of the two different sources.

Fig. 4. The Cerros del Rio dacite chill zone below the mafic tuff flow as described by Broxton et al., 2005.

The quarry occupies a 2- to 2.5-m thick, horizontal zone of black, massive [dacite] that forms the base of a thick Cerros del Rio lava flow exposed in a small butte near the Rio Grande (Fig. 4). The base of the lava flow is covered by talus, but tan-green, crudely-bedded, basaltic phreatomagmatic (maar) deposits that are exposed in the slopes a few meters below the quarry level. A basal flow breccia, if present, is covered by the talus (Broxton et al., 2005).

The basalt [dacite] contains sparse (1–2%), 0.5–1 mm olivine phenocrysts and 1–2 mm crystal aggregates (glomerocrysts) of olivine and clinopyroxene are evident in this section. [As with the other dacites in this study; see Fig. 2a here], the crystalline groundmass is so fine-grained that individual components cannot be identified with a hand lens. Except for a few thin horizontal gas segregation structures, the basalt is free of vesicles and is massive in nature.

Removal of large blocks of basalt from the quarry face is facilitated by a complex network of cross-cutting vertical and horizontal fractures, that was taken advantage of by the prehistoric knappers. These fractures include columnar cooling joints, curved fractures of various orientations, and horizontal fracture systems.

Unlike the Taos Plateau volcano sources, the Cerros del Rio source appears like a "true" quarry, with obvious destruction of the rock in the chill zone to extract large pieces, and a large debitage pile on the slope below with large flakes up to 30–40 cm in largest dimension. Large biface preforms and a broken quartzite hammerstone produced from a quartzite river cobble were also located. After looking at stone tool sources in the North American Southwest for over 30 years, Cerros del Rio dacite is one of the most impressive, similar to the mining at the Valles del Azufre obsidian source in central Baja California (Shackley et al., 1996). Very fortunately this is protected on Bandelier National Monument, and has been for nearly 100 years suggesting that the debitage pile is most likely prehistoric.

What is very different at this source as noted above is that the actual volume of raw material is much lower than the Taos Plateau sources, however certainly adequate to supply knappers throughout prehistory in the upper Rio Grande Valley. Along the five or so miles of trail from Frijoles Canyon and the Bandelier National Monument visitor center are numerous dacite flakes, and the two late period sites visited along the way exhibited abundant dacite debitage, along with obsidian and secondary siliceous sediments. Like Pot Creek Pueblo to the north reported by Jay Newman, dacite was used for the production of larger flake stone tools and even a few arrow points (Newman and Nielsen, 1987). Dacite was not restricted to the preceramic knappers tool kit, but used during Pueblo periods at least near the sources.

Table 1
Major oxide values for the three dacite sources in northern New Mexico and the WXRF and EDXRF analysis of AGV-1, a USGS andesite standard.

Source/Sample name	Sum	SiO_2	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	Na_2O	TiO_2
Mt San Antonio 061805-1-1	99.47	64.69	15.56	4.12	4.99	3.20	2.09	0.08	4.07	0.68
Cerros del Rio 3	99.19	63.89	15.88	4.54	4.70	2.65	2.30	0.08	4.53	0.63
Newman Dome 062510-1	99.87	63.82	14.86	4.99	6.36	2.80	2.34	0.12	3.74	0.83
AGV-1 (WXRF), $n = 1$	98.94	61.90	16.00	4.94	6.75	2.84	1.40	0.10	4.00	1.01
AGV-1 (EDXRF)	100.00	62.00	15.69	5.64	7.28	3.29	1.03	0.11	3.80	1.15
AGV-1 (USGS recommended)		58.84 ± 0.58	17.15 ± 0.34	4.94 ± 0.14	6.77 ± 0.19	2.92 ± 0.37	1.53 ± 0.093	n.r.	4.26 ± 0.12	1.05 ± 0.05

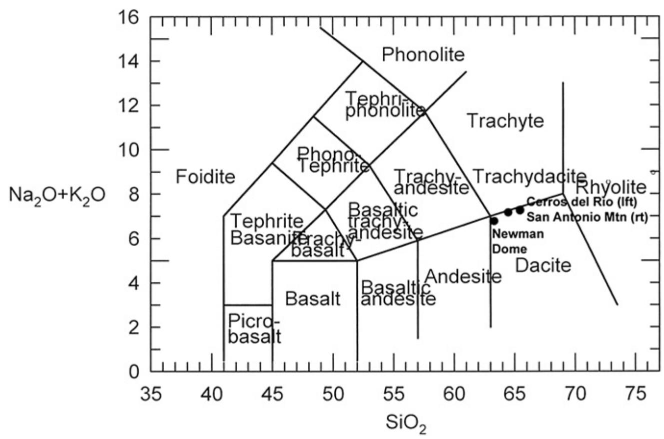

Fig. 5. Alkali–silica plot of the three high-alkali dacite sources from northern New Mexico (see data in Table 1).

3. Geochemistry and petrography of northern New Mexico dacite

What piqued my interest in the presence of this raw material in the region was the quality of this volcanic rock for the production of chipped stone tools. Like many others, I had ignored it in favor of the more ubiquitous obsidian common in all periods in northern New Mexico (Shackley, 2005a,b; Vierra 2010). The material was called "basalt" in the local vernacular mainly due to its dark grey color quite similar to basalt throughout New Mexico, indeed everywhere on earth. The geological context at Cerros del Rio even had a geologist confused as noted above. As I began to knap a few pieces from San Antonio Mountain and Cerros del Rio it became apparent that, 1) it did not act like basalt, and 2) that was the reason for its popularity in prehistory.

Table 2
Minor and Trace elemental concentrations for the three dacite sources in northern New Mexico.

Source/Sample	Ti	Mn	Fe	Zn	Ga	Rb	Sr	Y	Zr	Nb	Ba[a]
San Antonio Mtn											
061805-1-1	3610	742	36816	81	20	56	633	23	270	22	1405
061805-1-2	3395	632	34262	80	17	55	591	21	246	16	1370
061805-1-3	3683	548	34428	73	22	54	602	20	253	22	1516
061805-2-1	3425	497	31906	77	20	52	515	22	201	27	1402
061805-2-2	3665	633	35857	82	22	57	564	25	240	13	1439
061805-2-3	3389	646	34805	79	21	57	602	22	247	28	1251
061805-3-1	3561	609	35020	80	19	62	568	24	250	18	1405
061805-3-2	3227	617	31823	75	24	61	569	24	256	10	1531
061805-3-3	3521	651	32938	69	20	59	570	18	254	19	1519
061805-4-1	3421	567	32598	79	20	56	532	22	233	30	1581
061805-4-2	3300	550	33599	74	23	59	558	17	226	22	1520
061805-4-3	3391	605	33415	71	20	52	546	23	230	17	
061805-5-1	3581	716	35773	88	22	63	581	18	249	17	
061805-5-2	3537	684	34228	78	24	59	591	26	255	24	
061805-5-3	3143	586	32011	71	21	61	581	20	245	19	
061805-6-1	4485	767	44577	98	23	69	653	19	269	20	
061805-6-2	3264	674	35090	83	23	61	572	23	256	20	
061805-6-3	3326	765	35273	81	18	57	573	23	244	18	
061805-6-4	3393	631	34996	78	19	61	572	15	242	31	
061805-6-5	3799	587	36357	82	20	55	626	23	262	15	1558
061805-6-6	3682	527	35511	87	16	59	607	26	269	20	
Cerros del Rio											
3	3356	2583	29734	80	19	47	814	6	197	19	1701
1	2813	553	28290	76	20	41	771	15	193	23	1627
2	3363	640	33390	71	24	40	822	14	207	20	1503
4	3505	636	33790	89	18	49	826	16	200	12	1579
5	3497	627	33069	70	21	44	839	11	202	28	1684
9	3297	671	31776	71	19	49	806	15	208	19	1630
7	3393	699	34613	71	22	47	878	19	213	21	1565
8	3226	896	31766	71	19	39	813	15	198	32	1627
6	3001	645	30915	73	19	39	818	16	180	19	1445
10	3256	639	30699	74	19	42	814	13	206	25	1741
Newman Dome											
062510–2	4655	786	45688	78	20	72	238	22	100	18	465
062510–3	4239	782	45940	73	18	61	232	22	95	13	426
062510–4	4080	708	43733	77	15	66	216	20	90	18	456
062510–5	3940	700	41876	69	18	60	208	18	93	14	422
062510–6	3611	689	38690	66	20	60	204	17	92	15	464
062510–7	4498	836	48929	79	17	70	227	20	94	15	438
062510–8	3822	738	42838	72	19	63	214	22	94	16	484
062510–9	4222	763	45351	77	18	64	214	19	99	15	433
062510–10	3814	681	39779	70	18	61	209	18	94	14	510
062510–11	4487	780	48670	79	22	65	233	19	98	13	499
1987 sample[b]				62		50	214	15	82	8	
Berkeley analysis				67		51	217	15	84	8	
AGV-1 (standard)	5901	694	48990	83	21	67	659	22	229	13	1191

All measurements in parts per million. AGV-1 is a USGS andesite standard.
[a] Barium acquired for only selected samples.
[b] Analysis as reported in Newman and Nielsen (1987, 265).

3.1. Major oxide chemistry

In order to confirm the identity and trace element chemistry of the stone, a wavelength and energy-dispersive X-ray fluorescence analysis was designed (see also Boyer and Moore, 2001 for comparison). A fusion disk was produced from a single sample of San Antonio Mountain and Cerros del Rio rock and analyzed on the Philips 2400 WXRF instrument in the Department of Earth and Planetary Science at Berkeley for the light elements Na, Mg, Al, Si, K, Ca, Ti, Mn, and Fe reported as oxides (Table 1). One sample of Newman Dome rock was analyzed for the same elements as a whole rock sample on the ThermoScientific Quant'X EDXRF instrument in the Geoarchaeological XRF Laboratory at Berkeley for the same elements (Table 1). The detailed instrument methodology is available in Shackley (2005b, Appendix) and online at http://swxrflab.net/anlysis.htm. The EDXRF non-destructive analysis exhibits slightly more error than the destructive WXRF analyses, but is within one or two percent of standard (Table 1).

The alkali and silica oxides are plotted in Fig. 5, and it is obvious that these are not mafic rocks but highly siliceous and fit the dacite composition although the alkalis are quite high for most dacites. The Newman Dome is close to andesite in composition, probably a result of the magmatic relationship to the adjacent Cerro Montoso olivine andesite (see Lipman and Mehnert's, 1979, 298–299 compositional analysis of these two lavas). Indeed all these dacites are near the composition of trachydacites and trachyandesites, as seen in the thin sections (not illustrated here) that show a very glassy fabric, but with abundant parallel to sub-parallel plagioclase laths (Shackley, 2005a; Fig. 2a and b here).

3.2. Trace element chemistry

While the major oxides are quite similar in these three silicic volcanic rocks, the trace element chemistry exhibits good variability in some of the incompatible elements (Table 2; Fig. 6). The sources are easily discriminated in Sr and Zr, and somewhat with Rb and Ba (Table 2; Fig. 6). What is notable is that these dacite sources, like many obsidian sources, are relatively chemically homogeneous. The samples from each of these sources, except the very small Cerros del Rio, were collected in a number of localities to insure that the potential for variability could be captured (Shackley, 2005b). But for most of the incompatible elements, variability is nearly as limited as seen in many obsidian sources. This is likely due to the glassy nearly homogeneous nature of the rock with few mineral components. Barium appears to be one of the more variable elements, particularly in the San Antonio Mountain samples, possibly due to barium concentrations in the akali-feldspar (sanidine) that sometimes occurs in this dacite (Fig. 2a).

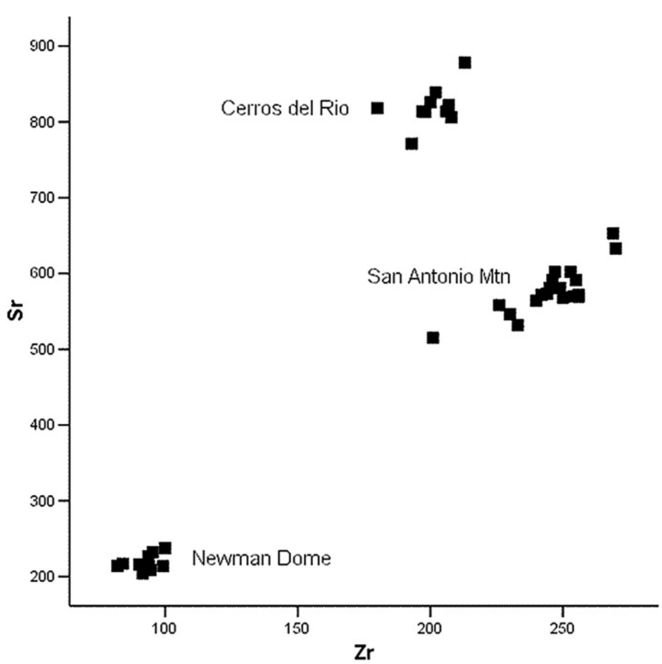

Fig. 6. Zr versus Sr bivariate plot of the three dacite sources from the data in Table 2.

4. Summary discussion

Dacite in northern New Mexico is a major source of archaeological stone throughout prehistory in the region. Analysis of early prehistoric assemblages in the region indicate that two dacite sources in the Taos Plateau Volcanic Field and one in the Cerros del Rio Volcanic Field supplied most if not all the dacite raw material for tool production, at least down into the middle Rio Grande basin. As mentioned earlier, while there are other intermediate (andesite) sources on the Plateau, nearly all the artifacts analyzed in this study and Newman's analyses at Pot Creek Pueblo were from the two dacite sources on the Plateau discussed here. I suspect, and continuing work will test this, that this is not sampling error, but a reflection of the greater utility of tool production from dacite versus andesite rock.

This very fine-grained, nearly glassy raw material was used to produce all forms of chipped stone tool classes, and appears to be nearly as valuable as obsidian in all time periods. Recent preliminary archaeological studies suggest that in concert with obsidian provenance studies, dacite can allow us to elucidate procurement and range, as well as exchange and group interaction during all periods in northern New Mexico and southern Colorado, particularly during Paleoindian and Archaic time periods (Shackley, 2005a; Vierra, 2010; Vierra et al., 2005).

The trace element chemistry indicates that these sources are chemically homogeneous and can be easily discriminated on at least two and probably four incompatible elements, Sr, Zr, and less so Rb and Ba. This is certainly an early stage of this research, but promises to enlarge our body of raw material that is amenable to provenance analysis. Research in Arizona on silicic volcanics suggests that other regions of the Southwest can benefit from provenance studies of dacite as well, although the sources there are not as well understood yet (Shackley, 1997a,b, 2009). Dacite can be as useful as obsidian provenance analysis in understanding social relationships in the Southwest apparently with as great a confidence as obsidian studies.

Acknowledgements

This research was supported, in part, by National Science Foundation grants BCS 0716333, and BCS 0810448. The results and inferences discussed here are not necessarily those of the National Science Foundation, however three of my colleagues are instrumental in piquing my interest in dacite as a major raw material in the Southwest. Jay Newman was the first to recognize the value of this raw material, not in Archaic period sites, but the late period Pot Creek Pueblo during his Ph.D. (Newman and Nielsen 1987). It was brought to my attention by Brad Vierra and Pegi Jodry who recognized the presence of this raw material in preceramic contexts in northern New Mexico. These colleagues deserve much of the credit for this research. Dave Broxton, geologist at Los Alamos National Laboratory I thank for discussions about the Cerros del Rio Volcanic Field and the dacite there.

Two reviewers, Bruce Huckell and Robert Dello-Russo, as well as one anonymous reviewer, offered comments that substantially improved the manuscript. Robert, who has worked on the Taos Plateau for many years, particularly in CRM contexts, steered me toward the unpublished gray literature on Plateau intermediate and silicic rock sources. I appreciate Robert's comments and advice, and was sorry to see that these rock sources that appear so important in prehistory have not been brought into the published record in any meaningful way – one stimulus for this study. Indeed, many of the references suggested are only available in the Office of Contract Archaeology, Maxwell Museum of Anthropology, University of New Mexico or in the CRM files of the contract companies that authored them. As a former CRM archaeologist for many years, I'm constantly concerned about all the good work that goes on in North America that is essentially unknown to all but a few, often only the authors.

Finally, the students in my Archaeological Petrology Summer Field School in New Mexico and the XRF Lab course at Berkeley deserve much of the credit for the lab analysis of these dacites, as well as hauling the Cerros del Rio dacite out of Lummis Canyon back to the Bandelier National Monument parking lot in near 100 degree weather. You have certainly made this all worthwhile, thanks. Thanks to Rory Gauthier and the staff at Bandelier National Monument who were very helpful in granting access and collections at the Cerros Del Rio Dacite Chill zone.

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