GEOCHEMICAL AND MINERALOGICAL ANALYSIS OF PRE-COLUMBIAN STONE TOOLS FROM LA PIEDRA PINTADA, BAJA CALIFORNIA SUR, MEXICO

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MASTER OF SCIENCE

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GEOCHEMICAL AND MINERALOGICAL ANALYSIS OF

PRE-COLUMBIAN STONE TOOLS FROM LA

PIEDRA PINTADA BAJA CALIFORNIA

SUR, MEXICO

Janice Michael McCabe, Candidate for the Master of Science Degree

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ABSTRACT

Piedra Pintada is located in San Pablo Canyon, one of a series of major canyons that bisect the mountainous interior of the southern Baja California Peninsula, Mexico. Among the resources used by the canyon's prehistoric inhabitants were lithic materials suitable for the production of flaked stone tools. To help better define the spatial scale of resource procurement by the canyon's prehistoric population elemental analysis of samples collected from the dikes and selected stone tools was done by ICPMS (Inductively Coupled Plasma Mass Spectrometry). ICPMS was used because it can provide elemental “fingerprints” that can be used to distinguish source materials and correlate specific stone tools with individual source material sites. Relative abundances of minor elements, including transition metals and rare earth elements, can differ sufficiently between source rocks that elemental ratios can be used to link a stone tool with its source material in many cases. Comparison of elemental

spectra from four stone tools with local dike rocks suggests that two of the four tools examined were manufactured from stone obtained from San Pablo Canyon.

APPROVAL PAGE

The faculty listed below, appointed by the Dean of College of Arts and Sciences have examined a thesis titled "Geochemical and Mineralogical Analysis of Pre-Columbian Stone Tools From La Piedra Pintada, Baja California Sur, Mexico," presented by Janice M. McCabe, candidate for the Master of Science degree, and certify that in their opinion it is worthy of acceptance.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Archaeological work in Baja California Sur, Mexico has revealed hundreds of prehistoric sites that were inhabited by native peoples. These hunter-gatherer groups extensively occupied the coasts, but frequently moved away from the coast and into the surrounding mountains for short periods to procure the available natural resources there (Carmean, 1994). Thus, understanding the archaeology of the Cape Region requires that these sites be placed in a larger geographical framework.

One way that the movements of prehistoric hunter-gatherers can be traced is through geological and geochemical studies that identify the sources of raw materials used to make the artifacts found at archaeological sites. Provenance studies have the potential to delineate the mobility patterns of prehistoric peoples.

The goal of this thesis is to clarify the nature of stone tool production and add to our current understanding of the mobility patterns of prehistoric peoples by using mineralogical and chemical techniques for "fingerprinting" potential sources of raw materials.

1.2 Culture

Native peoples have been in the Cape Region of southern Baja California for at least 10,000 years (Fujita, 2006). Approximately 450 sites, including habitation sites, shell middens, camps, lithic scatters, quarries, funerary sites, and pictography sites have been recorded in the Cape Region documenting its rich prehistory. At the time of historic contact, three language groups, the Pericú, Huchiti, and Guaicura were present in the Cape Region (Massey, 1949; Massey, 1955). The Pericú occupied territory from Bahìa Las Palmas south to the tip of the peninsula, including the Valle de Santiago, Sierra La Trinidad, west to Cabo San Lucas, and the Cape islands: Cerralvo, Espìritu Santo, La Partida and Isla San Jose located north of Bahía La Paz. The area from Todos Santos on the west, including the Sierras de La Laguna to the east coast from north of Bahía de Las Palmas to Bahía Las Paz was held by the Huchiti speaking people. The Guaicura claimed the Pacific coast, directly west of Bahía de La Pas north into the Magdalena Plains. Warfare was frequent between these groups (Massey, 1949).

The prehistoric inhabitants of the Cape Region were maritime hunter-gatherers. Faunal remains studied by Fujita (2006) suggest that these prehistoric peoples used subsistence strategies allowing them to take advantage of the diversified flora and fauna of the desert climate (Carmean, 1994). Most of the archaeological sites investigated in modern times are situated along the coast of the Baja Peninsula. The coastal location of the sites provided ready access to year-round fresh water, stable food supply, easy access to resources and relative security. Few investigations of interior sites have been conducted (Raab, M. 2004; Raab, A. 2005; Carmean, 1994), making the interior of the Cape Region relatively unexplored.

1.3 Physiography

1.3.1 Baja California Peninsula Overview

The Baja California Peninsula is situated along the northwest coast of Mexico (Fig. 1). It is approximately 1,500 km long and varies in width from 45 km to 230 km. The peninsula separates the Gulf of California, also known as the Sea of Cortez, from the Pacific Ocean. There are many contrasts in the physical terrain between mountain and plain, desert and ocean.

The Peninsular Range, which follows the length of the peninsula, is the most prominent physical feature. It is made up of four main ranges, Sierra de La Giganta, Sierra De San Pedro Mártir, Sierra de Juárez and Sierra de La Laguna. The eastern escarpments are much steeper and rugged than those of the west. Picacho del Diablo in Sierra San Pedro Mártir is the highest peaks on the peninsula with an elevation of 3,096 m. Pine-oak forests are found at the higher elevations of these ranges (Lozano-Garcìa *et a.l*, 2002).

The Baja California Peninsula landscape is relatively dry, supporting deserts, dry tropical forests and pine-oak woodlands. Climates range from Mediterranean in the north, desert along the eastern escarpments of the northern mountains and the central and southern plains and dry tropical forest in the Cape region.

1.3.2 Cape Region

The Cape Region (Fig. 2) has a unique environment in that it is the only part of the peninsula with a dry tropical climate. The Cape has two coastal environments. Sierra de La Laguna bisects the Cape Region on a north-south axis. The western flank is steep and gives way to coastal plains and foothills before reaching the dark blue waters of the Pacific Ocean. In contrast, the eastern escarpment drops gradually to the valley floor and fans out to the tranquil waters of the Gulf of California.

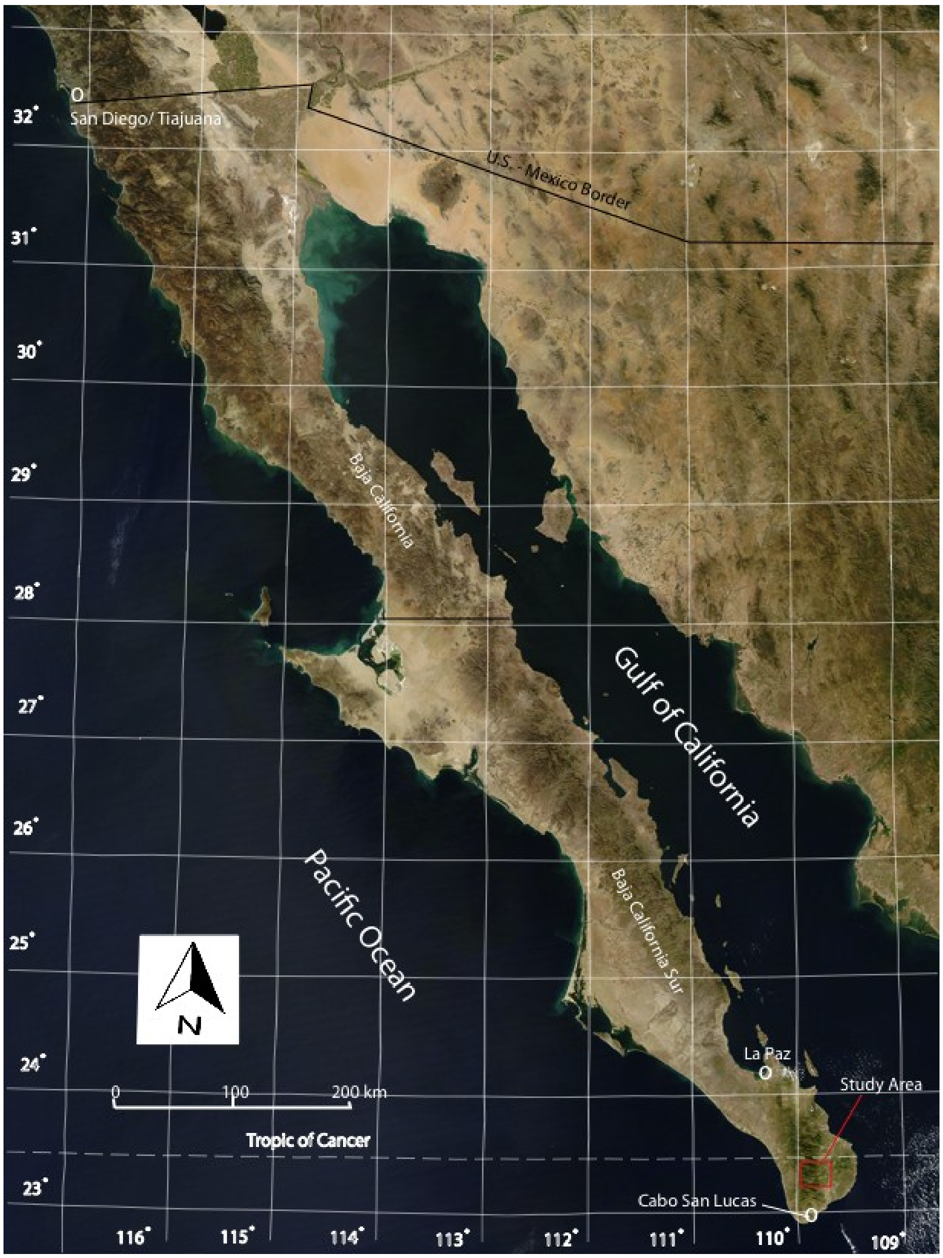


Figure 1 – Satellite image of Baja California Peninsula modified from Earth Snapshot at http://www.eosnap.com

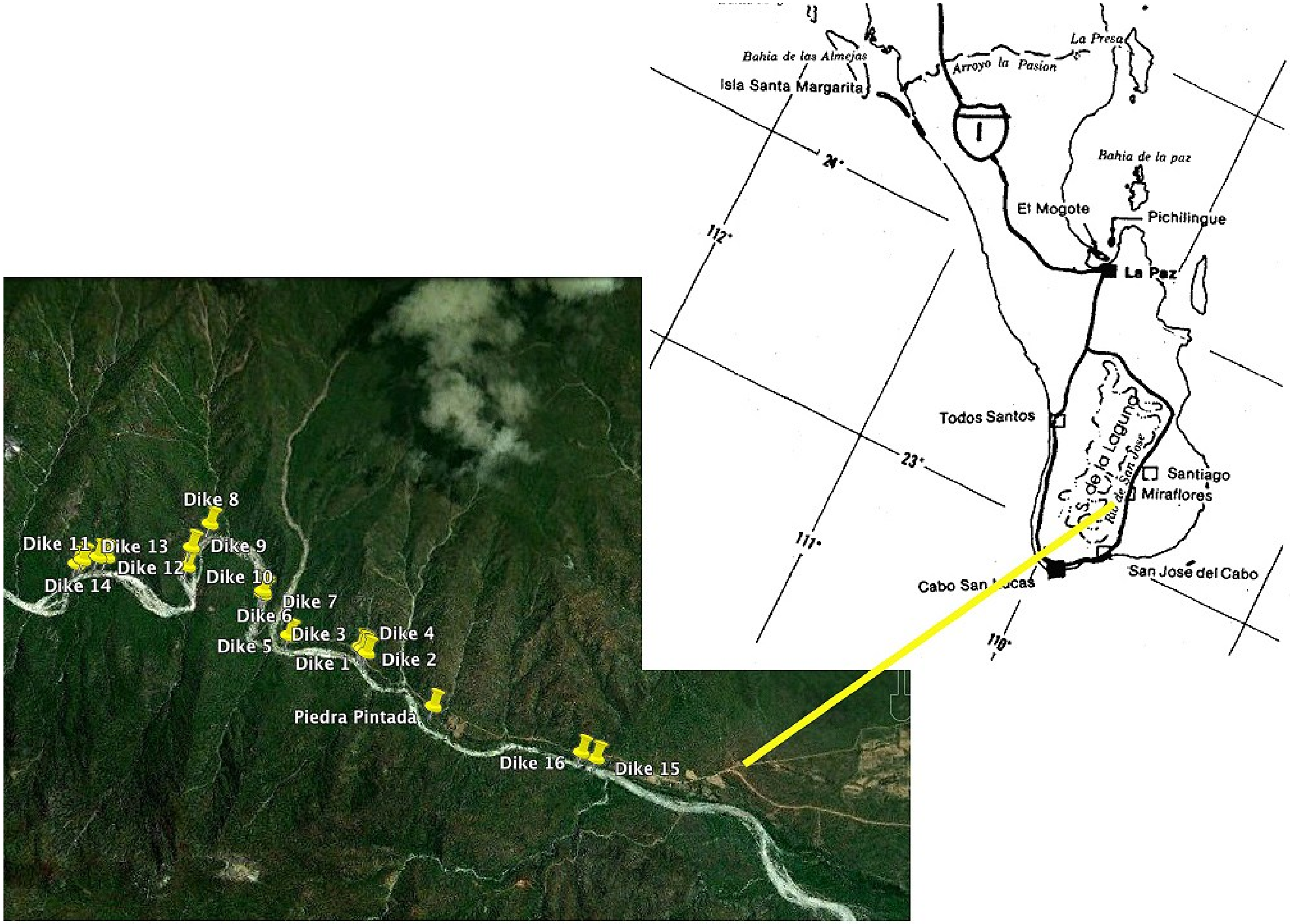


Figure 2 – Map and Google Earth images showing location of San Pablo Canyon and dikes.

CHAPTER 2

TECTONIC AND GEOLOGIC SETTING

2.1 Evolution of the Gulf of California

Prior to ~29 Ma ago, a convergent plate boundary between the Pacific basin plates and North America plate existed along the future western margin of Baja California (Atwater, 1970; Hausback, 1984; Lonsdale, 1989). The Farallon plate, the largest Pacific basin plate in this area, was being subducted under the North American plate faster than it was being created at the East Pacific Rise (Atwater, 1970; Atwater, 1989; Stock and Hodges, 1989; Atwater and Stock, 1998). At ~25 Ma, as the East Pacific Rise neared the subduction zone at the western edge of North America, the Farallon plate began to fragment, and the Pacific plate collided with North America beginning its subduction (Atwater, 1989; Stock and Hodges, 1989; Stock and Lee, 1994; Busch *et al.*, 2010). The collision of the Pacific-Farallon ridge with the subduction boundary triggered development of the Mendocino and Rivera triple junction, and a zone of right-lateral, strike-slip faulting along the west coastline of Baja California (Fig. 3. A) (Hausback, 1984; Stock and Lee, 1994; Busch *et al.*, 2010). During the early Miocene, subduction of the Farallon plate system continued lengthening the Pacific-North American transform plate boundary as the southern portions of the Farallon-Pacific spreading ridge continued to collide with North America (Fig. 3. A) (Atwater 1970). Between 20 and 12 Ma, the Guadalupe and Magdalena microplates began to form from the breakup of the subducting Farallon plate beneath North America. With the formation of the Guadalupe and Magdalena microplates subduction stalled, and the microplate were eventually captured by the Pacific plate. Cessation of subduction and the capture of the microplates led to the development of a right-lateral strike-slip zone, the Tosco Abrejos fault, at the location of the paleo-trench (Atwater, 1970; Stock and Hodges, 1989; Stock and Lee, 1994). The Tosco Abreojos fault zone accommodates much of the transform movement between the North American and Pacific plates (Atwater, 1970; Hausback, 1984; Stock and Lee, 1994; Umhoefer *et al.*, 2002).

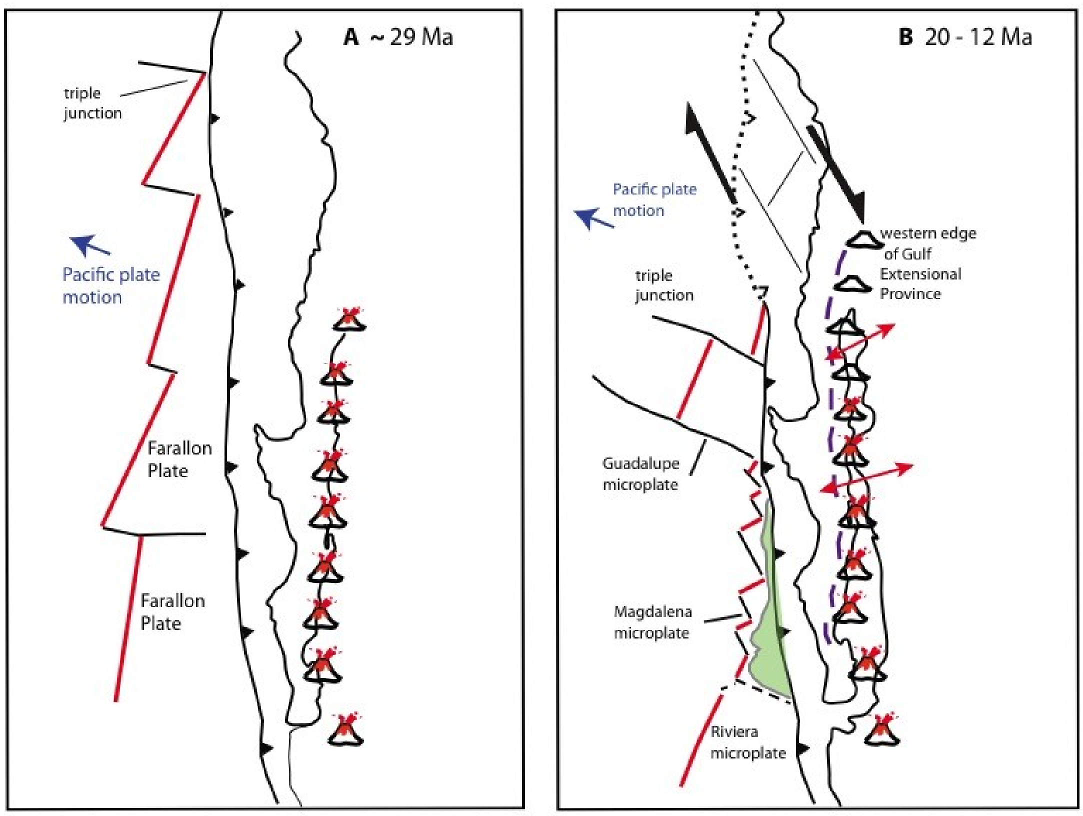
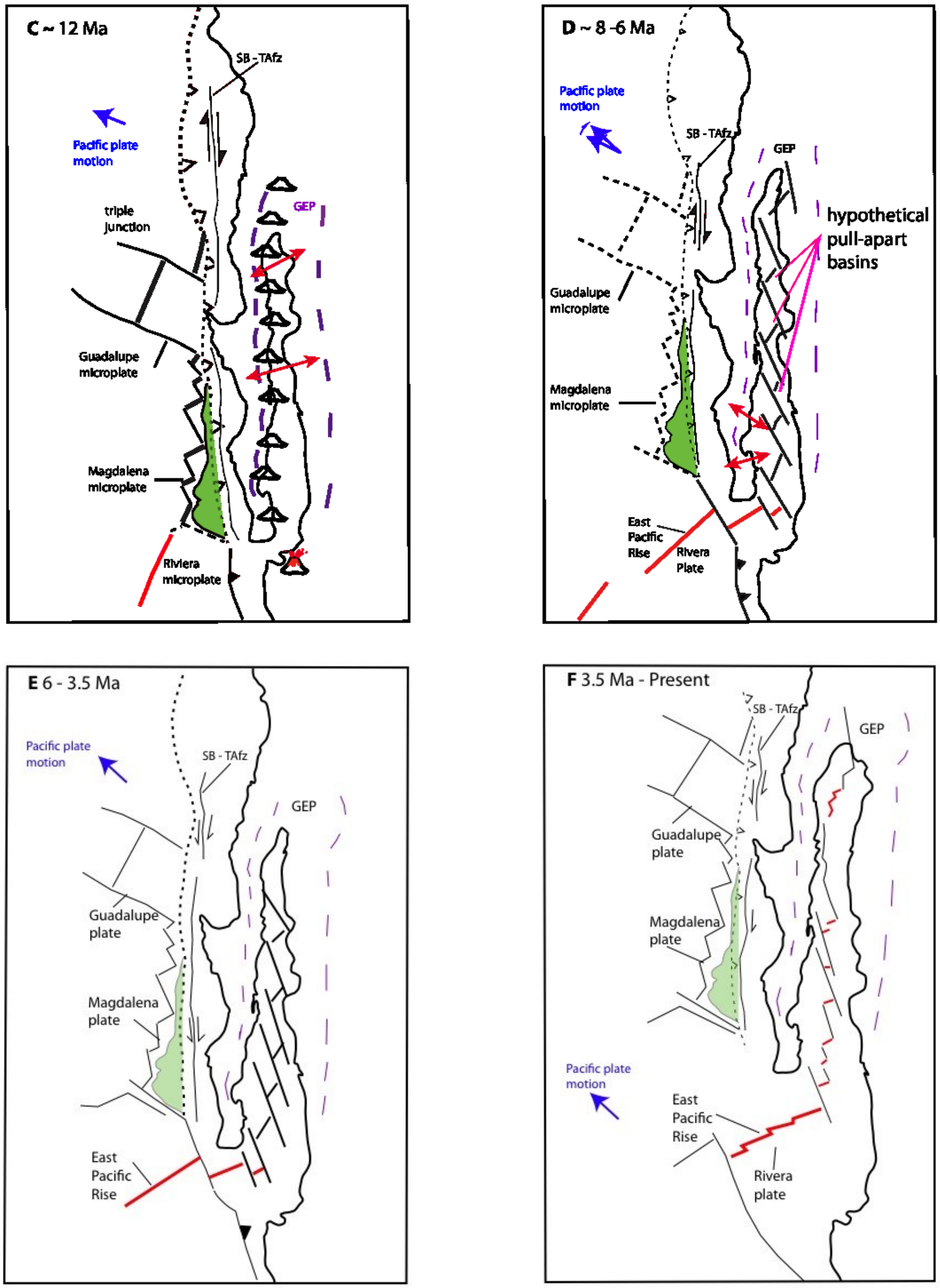


Figure 3 (A-F) - Continued on following page. Tectonic evolution of the Gulf of California since ~29 Ma. Plates and microplates represented include the Pacific, North American, Farallon, Guadalupe, Magdalena, and Rivera. Other abbreviations are: Gulf Extensional Province (GEP), San Benito-Tosco-Abreojos fault zone (SB-TAfz), Rivera triple junction (RTJ). Figure modified from Maloney (2009) and Fletcher (2007).



C ~ 12 Ma
SB - TAfz
Pacific plate motion
GEP
triple junction
Guadalupe microplate
Magdalena microplate
Riviera microplate
D ~ 8 -6 Ma
Pacific plate motion
SB - TAfz
GEP
hypothetical pull-apart basins
Guadalupe microplate
Magdalena microplate
East Pacific Rise
Rivera Plate
E 6 - 3.5 Ma
Pacific plate motion
SB - TAfz
GEP
Guadalupe plate
Magdalena plate
East Pacific Rise
F 3.5 Ma - Present
SB - TAfz
GEP
Guadalupe plate
Magdalena plate
Pacific plate motion
East Pacific Rise
Rivera plate

The tectonic evolution of the Gulf of California began ~12 Ma with a major plate reorganization that led to the cessation of subduction along the Baja California Peninsula, and to the initiation of extension in the Gulf of California region as the Pacific Plate began the capture of Baja California (Atwater, 1970; Stock and Hodges, 1989). Most researchers believe that the tectonic evolution of the Gulf of California occurred in two distinct extensional phases. The first phase, in the Middle to Late Miocene was initiated after the Rivera triple junction jumped southward to near the future mouth of the Gulf of California, which caused the plate margin to change from oblique convergence to trans-tension (Stock and Hodges, 1989). This extensional period was ENE directed and similar to the Basin and Range style of continental rifting that is associated with marine basin formation. Extension was partitioned by right-lateral strike-slip motion along the Tosco-Abreojos fault zone and normal faulting in the Gulf Extensional Province (Fig. 3. C) (Hausback, 1984; Stock and Hodges, 1989; Fletcher *et al*., 2007). Research by Spencer and Normark (1979) suggests that prior to the shift of plate motion into the Gulf Extensional Province the Tosco-Abreojo may have experienced as much as 272 km of right-lateral offset. However, another model proposes development from trans-tensional faulting across the Gulf Extensional Province with combined strike-slip and normal faulting (Gans, 1997; Fletcher *et al*., 2007). Data collected by Gans (1997) in southeastern Sonora suggests large magnitude NW-SE extension in the late Oligocene to middle Miocene occurred in northwestern Mexico while subduction was still ongoing. Such a large amount of extension during this timeframe conflicts with the model of Stock and Hodges (1989) which requires large magnitude extension in the Gulf Extensional Province during the late Miocene, for which evidence is lacking. Gans (1997) speculated that by 10 Ma the Baja California peninsula was suddenly transferred to the Pacific Plate, and that the majority of extension was accommodated by a system of en echelon strike-slip faults and oblique normal faults in the magmatically weakened "protogulf". Provenance studies of the Magdalena Fan by Fletcher, et al (2007) seem to support the model proposed by Gans (1997). The general consensus is that the Magdalena Fan originated near the present mouth of the Gulf of California and was translated northward 270 km along the Tosco-Abreojos fault zone (Lonsdale, 1991; Ferrari, 1995; Marsaglia. 2004). However, Fletcher *et al.* (2007) proposed a more northerly source region for the Magdalena Fan off the coast of southwestern Baja California, which suggests less than 150 km of cumulative dextral shear occurred on the faults west of Baja California (Fletcher *et al*., 2007). This model assumes the faults accommodated just a small fraction of the total Pacific-North American slip rate between ~12 and 6 Ma. and that the majority of displacement was accommodated across the Gulf of California extensional province by greater and earlier northwest directed shear (Fletcher *et al*., 2007).

The modern phase of rifting began ~ 8 - 6 Ma with the transition from transtensional faulting at the plate boundary to seafloor spreading and transform faulting within the Gulf of California (Fig. 3. D) (Fletcher and Muniguía, 2000; Umhoefer *et al*., 2002; Busch *et al*. 2010). During this period activity along the Tosco-Abreojos fault system diminished.

Because reconstructions of plate movement require dextral slip within the Gulf Extensional Province before plate boundary localization (Gans, 1997; Oskin and Stock, 2003), the period between 8 and 3 Ma may have been characterized by the development of pull-apart basins in the future Gulf of California (Lonsdale, 1989; Umhoefer *et al*., 2002), Extensional and strike-slip motion were active across the gulf axis system in the form of en echelon strike-slip faults (Fig. 3.E) (Lonsdale, 1989; Fletcher and Munguía, 2000). Umhoefer *et al*. (2002) and others have linked the evolution from "proto-gulf" rifting to seafloor spreading with a clockwise rotation of the maximum extension direction.

The Pacific-North American plate boundary was localized within the Gulf by ~ 6 Ma (Oskin *et al*., 2001). The presence of upper Miocene to lower Pliocene marine rocks in the northern Gulf of California, indicates that marine incursion from crustal thinning and localization of the Pacific-North American plate boundary occurred by ~6.5 – 6.3 Ma. In the southern Gulf, marine rocks indicate a marine incursion somewhere between 8 to 7 Ma which may have resulted from intense proto-gulf continental extension, the timing of which correlates well with observed plate motion changes at this time (Oskin and Stock 2003). Based on magnetic lineations at the Alarcón spreading ridge, seafloor spreading had initiated by 3.6 Ma (DeMets, 1995). By 2.5 Ma plate motion accelerated to 46 mm/yr and presumably transform faults formed along the Alarcón spreading ridge at that time (Fig. 3.F) (Umhoefer *et al*., 2007).

The transfer of Baja California to the Pacific plate is not complete, based on active transform faults west of the peninsula, recent seismicity at the southern end of the Baja peninsula away from the spreading centers and transform faults, and a deficit between the spreading rate of the Alarcón rise in the Gulf of California and the Pacific-North American plate boundary rate (Fletcher *et al*., 2000; Fletcher and Munguía, 2000; Plattner *et al*., 2007; Busch *et al*., 2010). The modern Gulf of California region is still characterized by highly oblique, divergent continental rifting (DeMets, 1995; Fletcher and Munguía, 2000; Umhoefer *et al*., 2002).

2.3 Volcanism

The magmatic evolution of the Gulf of California and Baja California is closely related to the tectonic history of the region. During the Miocene, several stages of volcanism took place in northwestern Mexico. The Sierra Madre Occidental, a volcanic belt composed of two vast igneous sequences of calc-alkalic volcanic rocks was built ~38 and 23 Ma (McDowell and Keizer, 1977; Cameron *et al*., 1980; Bellon *et al*., 2006). Ignimbrites, lavas, and composite batholiths compose the oldest sequence, and are similar in composition and age to the batholithic terranes of the Basin and Range of the United States (McDowell and Clabaugh, 1979). The younger sequence erupted between 34 and 27 Ma, with activity persisting until ~ 19 Ma, and is composed of rhyodacitic to rhyolitic ignimbrites (McDowell and Clabaugh, 1979; Ferrari *et al.,* 1999) (Fig. 3A). The region to the west that would become Baja California was a stable marine continental shelf receiving volcanic detritus from the active Sierra Madre Occidental volcanic arc during this time period (Hausback, 1984). Volcanic activity migrated westward and arrived along what is now eastern Baja California between 24 and 11 Ma, forming the Baja Peninsular Range, a subduction-related calc-alkaline volcanic arc (Hausback, 1984; Sawlan, 1991; Umhoefer *et al*., 2001; Bellon *et al*., 2006; Calmus *et al*., 2010) (Figs. 3B and 3C). Volcanism north of the Pacific-Farallon-North American triple junction gradually extinguished between 16 and 10.5 Ma as extension in the Gulf Extensional Province initiated (Stock and Hodges, 1989; Sawlan, 1991; Nicholson *et al*., 1994) ~12 Ma the calc-alkaline volcanism in central and southern Baja

California changed to adakites resulting from partial melting of subducted oceanic crust, magnesian andesites from a mantle metasomatized by slab-derived melts, and tholeiitic basalts without a clear subduction identity when the subduction of the Guadalupe and Magdalena microplates ceased (Benoit *et al*., 2002; Calmus *et al*., 2003; Conly *et al*., 2005; Pallares *et al*., 2007). At the onset of rifting in the Gulf of California ~ 12 Ma tholeiitic lavas began erupting. The composition of these magmas varies depending on the stage of rifting at the time of eruption and on their location (Sawlan, 1991). They range from tholeiites, similar to ocean island basalts and continental flood basalts, to mid-ocean ridge basalts.

CHAPTER 3

ARCHAEOLOGICAL SITE SETTING

San Pablo Canyon is one of many east-west trending canyons on the eastern flank of Sierra de la Laguna in the Cape Region of the Baja California Peninsula (Fig. 2). Piedra Pintada is located about two kilometers from the mouth of San Pablo Canyon (Fig. 4). It is situated on the north side of San Pablo Canyon on a bench about 30 m above the canyon bottom with the walls of the narrow canyon rising steeply about 1,200 m on either side. The site is situated on deposits that appear to be alluvial and colluvial in nature. Large boulders littering the canyon and the bench suggest deposition by high-energy climatic events during the Pleistocene (Raab *et al.*, 2004) (Fig 4). After deposition of these boulders, the new flood channel appears to have filled gradually with sediments eroded from hill slopes on the northern margin of the channel. This sedimentation buried the prehistoric archaeological deposits flanking Piedra Pintada.

The Piedra Pintada archaeological site takes its name from a large granite boulder bearing panels of pictographs executed in red paint (Fig. 5). The rock art at this site was first discovered by the Dutch anthropologist Herman ten Kate in 1863 and contain pictographs, which include geometric lines and dots, ovals with a line through them and handprints (ten Kate, 1883) (Fig. 6). In 1983, Reygadas and Velásquez first excavated at the site, and unearthed several hearth features and flakes of igneous rock (Reygadas *et al.,* 2006). A more detailed excavation was done during January, 2004 by L. Mark Raab, Fermin Reygadas and Matthew Boxt (Raab *et al.,* 2004). It is from their excavation that the stone tools used in this investigation were discovered

Figure 4 – View of San Pablo Canyon. Photo by Mark Raab.

Figure 5 – Piedra Pintada Photo by Mark Raab.

Figure 6 – Rock art with geometric lines on west side of Piedra Pintanda. Photo by Mark Raab.

Two sites were chosen near the Piedra Pintada for excavation based on the results of auger testing (Fig. 7). The first site was located next to Piedra Pintada, because auger tests showed this area to have a heavy concentration of cultural material. It consisted of five 1-meter squares. The second excavation site (Unit 1) was located west of Unit 3 over what appeared to be a prehistoric earth oven, which was visible on the surface. A control unit, 15N/11-12E, was located south of the other units near the margin of the site to determine the nature of cultural deposits.

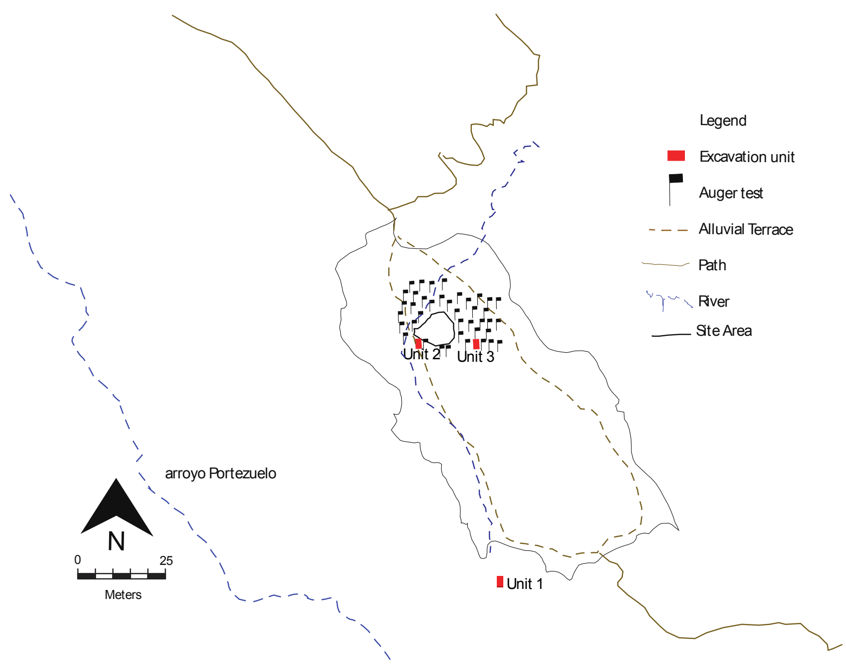


Figure 7 - Site map of Piedra Pintada modified from Raab *et al.*, 2004 and Brasket, 2007.

Units 2 and 3 were excavated to a depth of 40 cm and 170 cm respectively when sterile deposits were reached. Unit 2 at the base of Piedra Pintada on the south was still producing cultural material when the field season ended (Fig. 8). At that point it consisted of five subunits (3N/8E, 3N/9E, 3N/10E, 3N/11E and 3N/12E) and excavation was at 150 cm (Raab *et al*, 2004; Brasket, 2007). The artifacts used for this project were collected from Unit 2.

Materials recovered from Unit 1 included seeds, rock debitage, fire affected rock, a mano, charcoal, wood fragments, and bone. Unit 2 yielded debitage, utilized flakes, quartz shatter, manos, floral matter, carbon, bone fragments, and unidentified shell pieces. The excavation team also recorded several thermal features consisting of fire- affected rock, charcoal and darkly burnt sediments, which are believed to be hearths.

Figure 8 – Unit 2 excavation pit showing features uncovered. Photo by Mark Raab.

CHAPTER 4

METHODOLOGY

4.1 Field Methods

Site description and rock sampling from dikes for this study within San Pablo Canyon, Baja California Sur, Mexico (Fig. 1) were conducted over a three-day period during March 2006. The location (GPS) and orientation (Brunton compass) of each dike was determined. Samples were collected from the dike interior and chilled margins using non-weathered areas as much as possible. The samples were labeled and placed in bags.

Our goal was to travel 4 km westward from Piedra Pintada and 2 km eastward to the mouth of the canyon collecting samples from dikes found along the way. Over the two days spent hiking the canyon, we encountered 18 dikes (Table 1). There were five dikes that were not sampled. Three appeared to be extensions of dikes already sampled, one was a porphyritic andesite, material not suited for tool making, and one dike was heavily altered. Several of the dikes stood out from the others. The first was Dike 5, which was the largest at ~ 29 m in width. It was a composite dike with distinct contacts (Fig. 9). One side (D5A) was in contact with granite, gneiss, and schist and had an aphanitic texture, becoming finer grained and lighter in color (slightly pinkish) closer to the contact with the other side (D5B). D5B also had an aphanitic texture and seemed to be very thick. Its texture coarsened at the contact with D5A.

Figure 9 - Sampling at dike 5. Photo by Mark Raab.

Approximately 2 km west of dike 5 along the right bank of the channel was a highly altered diorite dike, heavily fractured with a network of white veins throughout, possibly the result of hydrothermal alteration. Due to its heavy alteration, no sample was collected.

TABLE 1.—DIKE LOCATIONS AND DESCRIPTIONS

Dike #	*Latitude*	*Longitude*	*Dike Trend **	*Description*	*Samples*
1	N23° 20' 11.4"	W 109° 51' 22.8"	N9E	Diabase, chilled aphanitic margin, porphyritic core	1 & 1CM
2	N23° 20' 12.2"	W 109° 51' 23.8"	NR	Diabase, cut by gneiss	2
3	N23° 20' 12.5"	W 109° 51' 24"	NR	~15 cm wide thinning to ~ 2.5 cm	3
4	N23° 20' 12.6"	W 109° 51' 24.5"	N65E	~2 m wide	4
5	N23° 20'12.21"	W 109° 51' 50.1"	N40E	Composite with distinct contacts ~29 m wide	5A, 5B, 5CM & 5A/B
6	N23° 20' 21.8"	W 109° 51' 50"	N65W	Diorite, ~2 m wide	6
7	N23° 20' 22.5"	W 109° 51' 50.1"	N45E	Diabase, ~ 7 m wide	7 & 7CM
NS1	N23° 20' 33.7"	W 109° 51' 53.8"	NR	Diorite crosscut by basalt	NS
NS2	N23° 20' 34.2"	W 109° 51' 54.4"	N25E	Diabase ~3 m wide	
8	N23° 20' 36.2"	W 109° 52' 5.0"	N55W	Diabase, porphyritic ~ 1-1.5 m	8
NS3	N23° 20' 30.7"	W 109° 52' 8.8"	N85W	Andesitic porphyry, 6 m	NS
10	N23° 20' 26.0"	W 109° 52' 9.4"	N30E	Aphanitic basalt, ~ 25 cm wide	10
NS4	N23° 20' 18.7"	W 109° 52' 16.7"	N80W	Diorite, highly altered, heavily fractured with a network of white veins throughout.	NS
NS5	N23° 20" 25.9"	W109° 52' 29.2"	N80W	Diorite, may be extension of previous dike ~ 12 ft. wide	NS

TABLE 1. - CONTINUED

12	N23° 20' 25.6"	W 109° 52' 31.2"	N30E	Diabase, splits and rejoins ~1.2 m wide, a 20 cm section embedded in a coarser basalt (12F came from this)	12 & 12F
13	N23° 20' 24.6"	W 109° 52' 34.8"	N35E	Diabase ~ 76 cm wide	13
14	N23° 20' 23.5"	W 109° 52' 36.2"	N25E	Multiple coarse textured basalt dikes, varied in color from red to greenish gray. ~ 12.2 m wide	14
15	N23° 19' 53.5"	W 109° 50' 22.4"	NR	Diabase	15
16	N23° 19' 54.5"	W 109° 50' 26.3"	NR	Diabase	16

NS – No sample taken NR-No reading taken

4.2 Laboratory Procedures

The laboratory procedures used to analyze the rock samples collected and select artifacts from the archaeological site are discussed below. Laboratory analyses used for this project include: (1) Inductively coupled plasma mass spectrometry (ICPMS), (2) X-ray diffraction analysis, and (3) thin section petrography.

Because the analytical methods used required destruction of material only four artifacts were chosen for analysis (Fig. 10).

4.2.1 Sample Preparation

Sample chips approximately 3 x 10 x 15 mm were cut from the stone artifacts (Table 2) and the dike samples (Table 1), except dike sample 5A/B, using a thin-bladed diamond saw and diamond-blade rock saw respectively. The weathered edges were removed with the rock saw, and small pieces were then taken from near the center of the cut samples. The pieces were then rough ground using an iron mortar and pestle. A mortar and pestle made from agate was used to grind the samples to a fine powder for subsequent digestion.

4.2.2 Artifact Description

The artifacts used in this research were found near a hearth (Fig. 8). These artifacts along were analyzed for plant and animal residues, but the results were negative for these artifacts themselves, however, soils collected in the same location as artifacts 20 and 266 tested positive for guinea-pig and agave respectively (Brasket, 2007). Figure 10 depicts the actual sizes of the artifacts. Tools 17 and 266 are utilized flakes, which are pieces of material that have been purposefully broken off of a larger piece of rock in the tool making process.

Flakes such as these with sharp edges were sometimes used as scrapers or as cutting type tools. Tool 20 is a fragment from a metate. A metate is a slab used for grinding of grains. Metates are usually coarse grained rock to make the grinding process easier. Tool 269 is a mano, which was used for grinding grains much like a pestle is used today.

TABLE 2.--ARTIFACTS FROM PIEDRA PINTADA

Accession Number	**Provenience**	**Artifact Type**	**Weight (g)**	**Dimensions (mm)**
17	Unit 1 3N/12E 120-130 cm	Utilized flake	109.9	L 79.68 W 54.57 H 21.52
20	Unit 1 3N/10E 130-140 cm	Metate fragment	71.4	L 45.47 W 39.66 H 25.47
266	Unit 1 3N/11E 130-140 cm	Utilized flake	261.7	L 77.96 W 70.45 H 22.32
269	Unit 1 3N/11E 60-70 cm	Mano	521.4	L 89.01 W 75.62 H 53.78

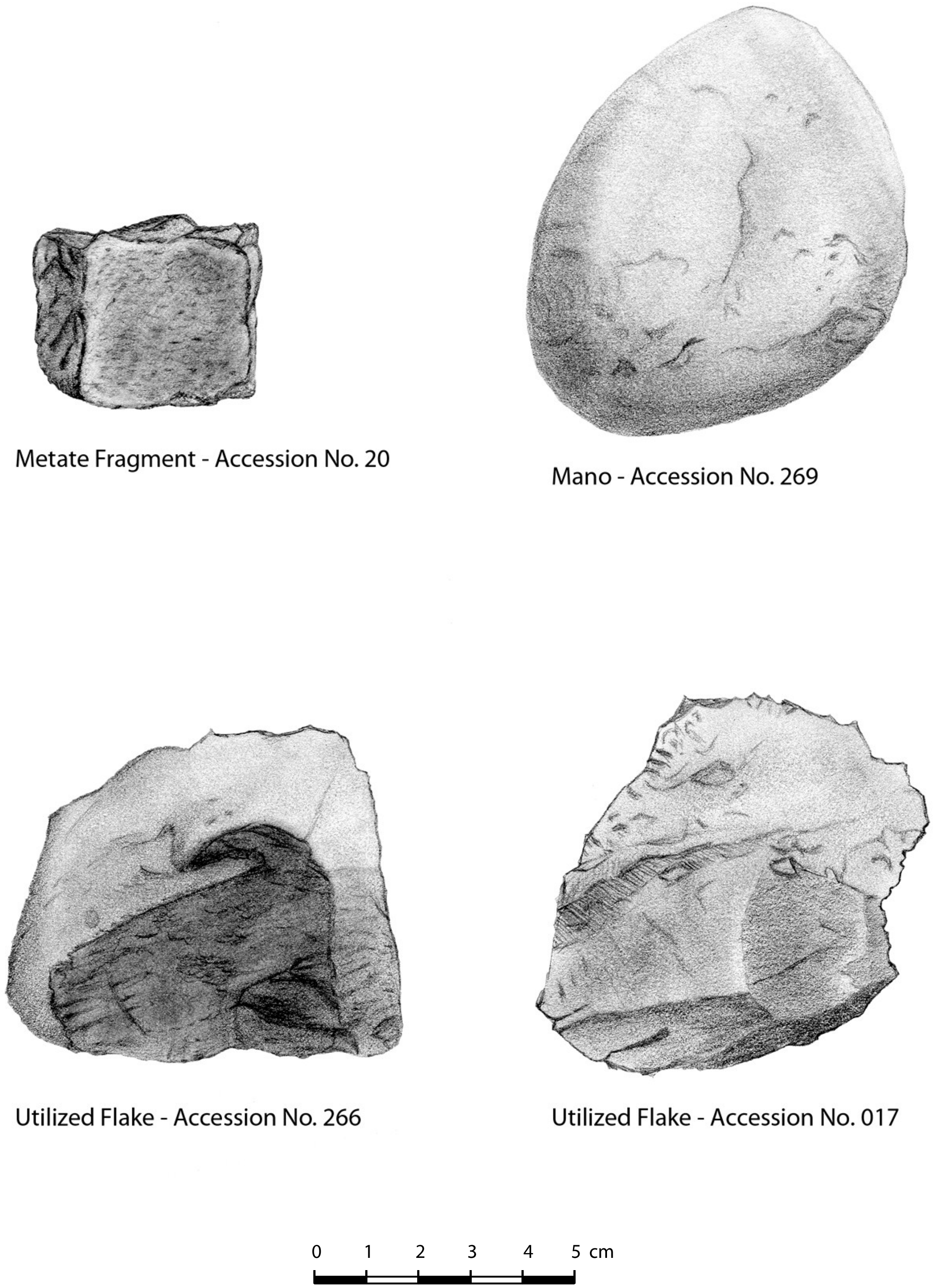


Figure 10 – Drawings of artifacts from Piedra Pintada excavation that were used for analysis. Drawing by Colby McCabe.

4.2.3 Microwave Digestion

In order to perform analysis by inductively coupled particle mass spectrometry, a homogenous solution is needed. Solid materials such as geological, environmental, biological, and metallurgical must be dissolved prior to analysis. Because of the nature of the samples, microwave digestion with concentrated, double sub-boiling distilled nitric and hydrofluoric acid was the method chosen. Once ground and homogenized, sample aliquots weighing approximately 0.05 grams were placed in a fluoropolymer reaction vessel used for microwave digestion. One milliliters of hydrofluoric acid was added along with three milliliters of nitric acid. The vessels were then capped and placed in the carousel of the CEM Mars 5 microwave oven. The microwave was set to the parameters shown in Table 3.

TABLE 3.--MICROWAVE OVEN DIGESTION PARAMETERS USED

Watts	**Power Setting**	**Run Time**	**Temp**	**Hold Time**
600	80%	2 min.	165°	2 min.
600	80%	5 min.	175°	8 min.

After digestion, the vessels were removed from the carousel, opened and placed upright in a warm sand bath for 24 hours and evaporated to dryness to eliminate and remaining hydrofluoric acid. The dried samples were re-dissolved with one ml of nitric acid. The sample solution was then poured into a pre-washed LDPE bottle. The microwave reaction vessel was rinsed three times with a small amount of 18 MΩ water, and was poured into the specimen bottle after each rinse. The bottle was placed back on the scale and additional 18 MΩ water was added to make a 100.00 g solution for presentation to the ICPMS.

4.2.4 Inductively Coupled Plasma Mass Spectrometry

Once the specimen solutions were prepared, inductively coupled plasma mass spectrometry (ICPMS) was used to determine rare earth element and trace metal concentrations in the samples.

Four sets of calibration standards were made. Standards for trace metals were mixed at dilutions of 50 ppb and 100 ppb for Ag, Al, As, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cs, Cu, Fe, Ga, Ge, Hf, Hg, In, K, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, Re, S, Sb, Se, Si, Sn, Sr, Ta, Ti, V, W, Zn, Zr using multi-element standard solutions CCS4, CCS5, CCS6 from Inorganic Ventures, Inc. (Christiansburg, Va). Standards for rare earth elements were mixed also at dilutions of 50 ppb and 100 ppb using multi-element standard solutions CCS1 and CCS2 from Inorganic Ventures, Inc. – Rare Earth Elements and CCS2 – Precious Metals. An internal standard solution containing In was mixed separately rather than being added to the other solutions, and teed in with the sample solution during analysis.

Operation parameters for the Varian UltraMass ICP-MS were set as shown in Table 4. The aerosol was generated using a concentric nebulizer and a pumping rate of ~2 ml/min. A T-tubing arrangement was used to mix and feed the internal standard and sample solutions to the nebulizer.

TABLE 4.--ICP-MS MEASUREMENT PARAMETERS

Analysis Modes	
Analysis Type	Quantitative
Peak Hopping	Spacing of 0.025 AMU
Number of Scans	3 per peak, 20 per replicate, 15 replicates per sample
Scan Time	400 msec with a replicate time of 7.99 sec.

Plasma Settings	
Plasma flow	15.0 L/min.
Auxiliary flow	1.10 L/min.
Nebulizer flow	1.01 L/min.
Sampling depth	11.0 mm

Optics Settings	
Lens	**Voltage**
Extraction	-304
First	-276
Second	-11.4
Photon Stop	-13.
Third	2.4
Fourth	-99

Internal Standards – Rare Earth Elements	
Isotope	**Used for elements**
Ru101	Sc, Y
Pd105	La, Ce, Pr, Nd
Pm147	Sm
Pt195	Eu, Gd, Tb, Dy
Ho165	Er, Tm, Yb, Lu, Th, U
Rh103	
Ir193	
Au197	
Internal Standards – Transition Metals	
Isotope	**Used for elements**
Sc45	Al, Ti, Cr, Mn, Fe, Co, Ni, Cu, Zn
Tb159	Ba
Y89	Rb, Sr, Zr, Nb, Sn

4.2.5 X-ray Diffraction

To determine the mineral content of the dike samples and the artifacts, X-ray diffraction analysis (XRD) was performed using a Rigaku Miniflex powder X-ray diffractometer with Co Kα radiation. Samples from the dikes and artifacts were ground to a fine powder using a mortar and pestle. Approximately 1 gram of powdered sample was mixed with 0.111 grams of zinc oxide (ZnO), and scanned at 1° 2θ/minute from every minute. Jade l.c.V.8 (MDI, Livermore, Ca) and RockJock 7 (Eberl, 2008) software were used for peak identification and quantitative phase anyalysis

TABLE 5.--MINERAL COMPOSITION (wt. %)

	Quartz	Ab+Olig	An+Anorth	Magnetite	Augite	Chlorite	Amphibole	Micas	Titanite
1C	6.88	53.44		7.74	25.43	6.51			
1M	4.35	53.64		5.80	15.85	33.75			
2	4.10	51.71		6.70	20.50			8.20	
3	1.00	45.28		19.40	24.81	9.54			
4	8.98	54.51		5.39	22.04	8.98			
5A	4.41	55.14		5.54	15.14	19.77			
5B	2.79	47.10		5.69	14.40	22.54		7.48	
5CM	2.70	45.70		3.50	20.00	20.70		7.40	
6	24.00	58.96		1.33				15.71	
7M	2.64	44.83		15.30	5.38	31.86			
8	17.85	58.81		1.00	4.94			17.62	
10		39.29		21.09	11.03			28.59	
12	4.43		66.17	4.88	11.80			12.71	
12F	5.47		61.00	4.64	10.23	6.42		12.25	
13		20.27	35.55	10.40	9.36			24.43	
14	8.01		58.92	4.06	9.37	4.18		15.46	
15	4.21		60.64	5.99	13.86	10.09		5.21	
16	4.75		60.33	3.33	14.96	12.59		4.04	
17-Tool	34.39	38.71	17.70		5.11			4.99	4.20
20-Tool		13.70	78.30	2.80	5.20				
266-Tool			69.20				27.06	3.74	
269-Tool	4.30	60.70		2.70	17.10			15.30	

CHAPTER 5

GEOCHEMICAL ANALYSIS

5.1 Variation Diagrams

Trace elements, which include transition metals and rare earth elements (REE), are often used to discriminate between petrological processes because they commonly substitute for major elements in the rock-forming minerals (Rollinson, 1998). Some trace elements remain relatively immobile during weathering, low-grade metamorphism and hydrothermal alteration, the REE more so than the transition metals. Although 19 rare earth elements (REE) and 15 trace metals were analyzed, only select REE and trace metals were chosen for analysis because they are commonly used by researchers in classifying volcanic rocks (Pearce, 1995; Calmus, *et al.*, 2010).

Trace element data can be grouped in many different ways to illustrate their distributions. For this study, I chose to use REE normalized to the average of C1 chondrites based on Evensen, *et al.* (1978) found in Rollinson (1998) (Fig. 11), transition metals and incompatible multi-elements normalized to the primitive mantle based on McDonough *et al* (1992) found in Rollinson (1998) (Figs. 12 and 13), and a discrimination plot based on Pearce (1996) found in Rollinson (1998) using incompatible elements Nb/Y versus Zr/Ti (Fig. 15).

The most noticeable feature of the REE plot is Tool 17, which has an opposite trend than the other samples, specifically in europium (Eu). Tool 266 and dike sample 6 show depletion in Eu and Yb. The overall plot trend of most of the samples is flat (not much deviation), typical of basalts (Rollinson, 1998; Calmus, *et al.*, 2010).

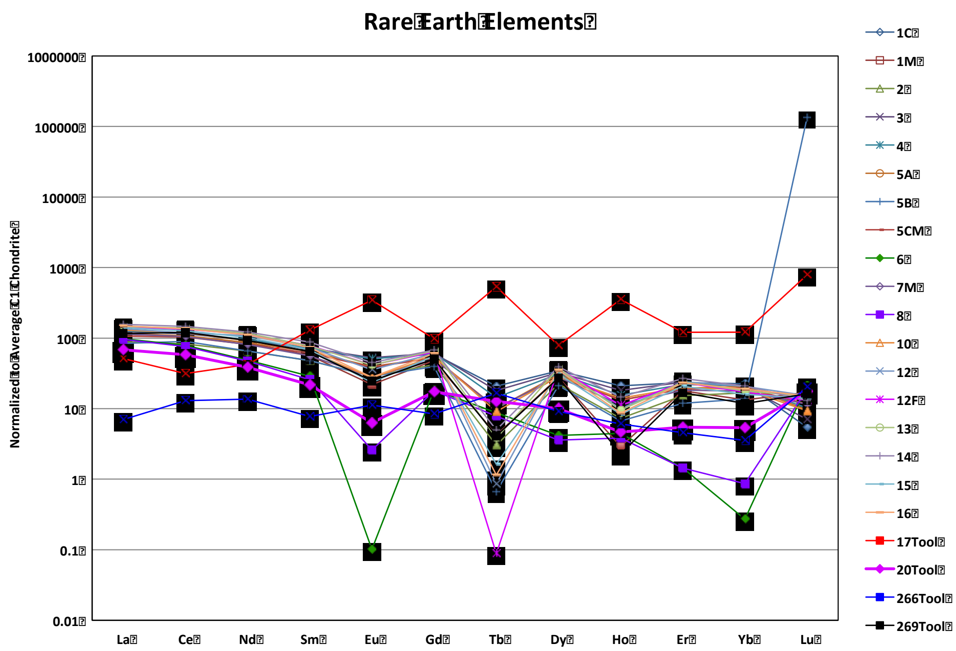


Figure 12- Rare earth elements normalized to average of C1 chondrite based on Evenson *et al.* (1978). Note the anomalous behavior of the plot for tool 17.

The same flat trend can be seen in the plot of incompatible elements (Fig. 13). However, there are several that stand out from the others, in particular tool 266, because it has a much lower concentration of rubidium (Rb) and zirconium (Zr) than any of the others. Dike samples 6 and 8 also have lower concentrations of Zr. Tool 17 is deficient in strontium (Sr), titanium (Ti), and dysprosium (Dy). Tool 20 has slightly lower concentrations of most of the incompatible elements than the average of the dike samples, but follows the same general trend. Since the values of most of the dike samples are similar, taking an average allows the composition difference of those mentioned above to be better seen (Fig. 13).

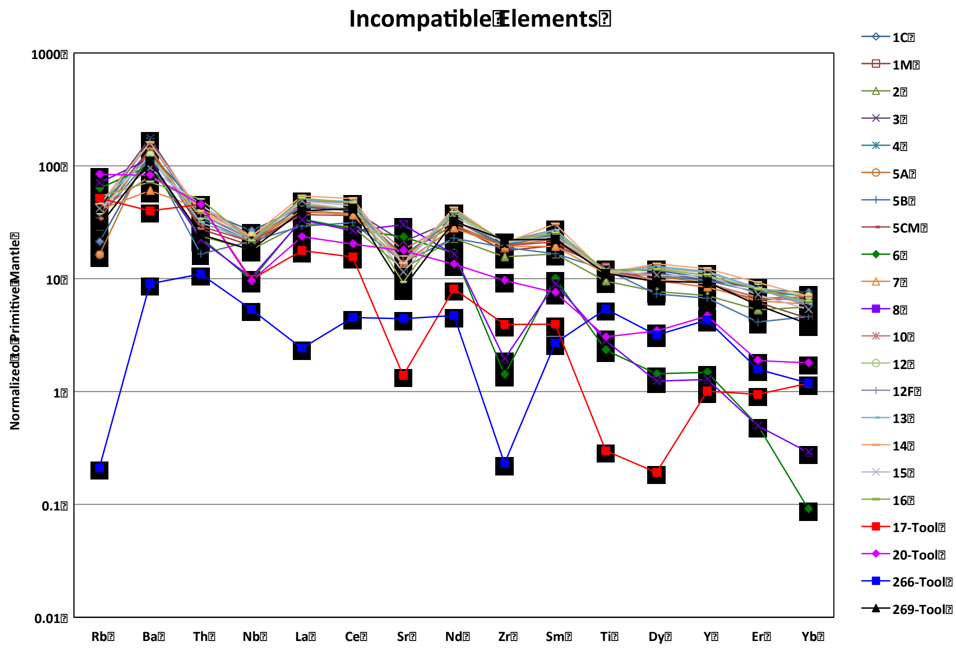


Figure 12- Incompatible multi-element patterns of dike and tool samples normalized to the Primitive Mantle of McDonough *et al.* (1992).

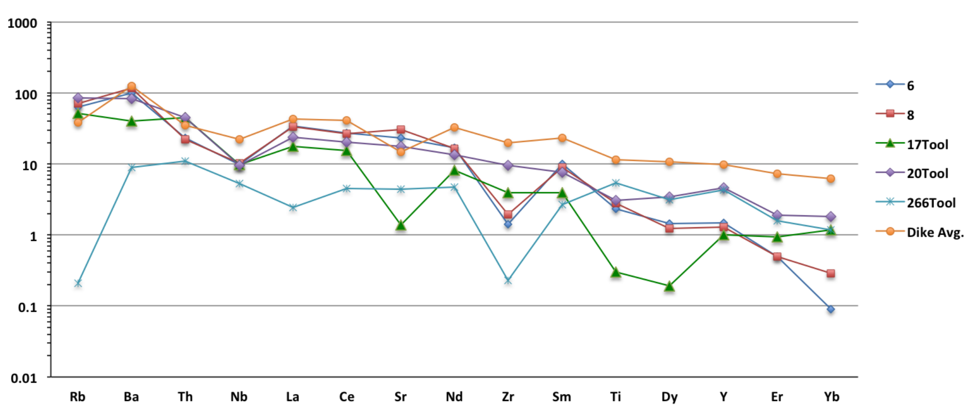


Figure 13 – Incompatible multi-element patterns of dike sample average compared to dike samples 6 and 8, tools 17, 20 and 266.

The plots of samples 6 and 8 and tools 17 and 266 also show a greater degree of variation in the transition metals (Fig. 14), although the general pattern is the same for all.

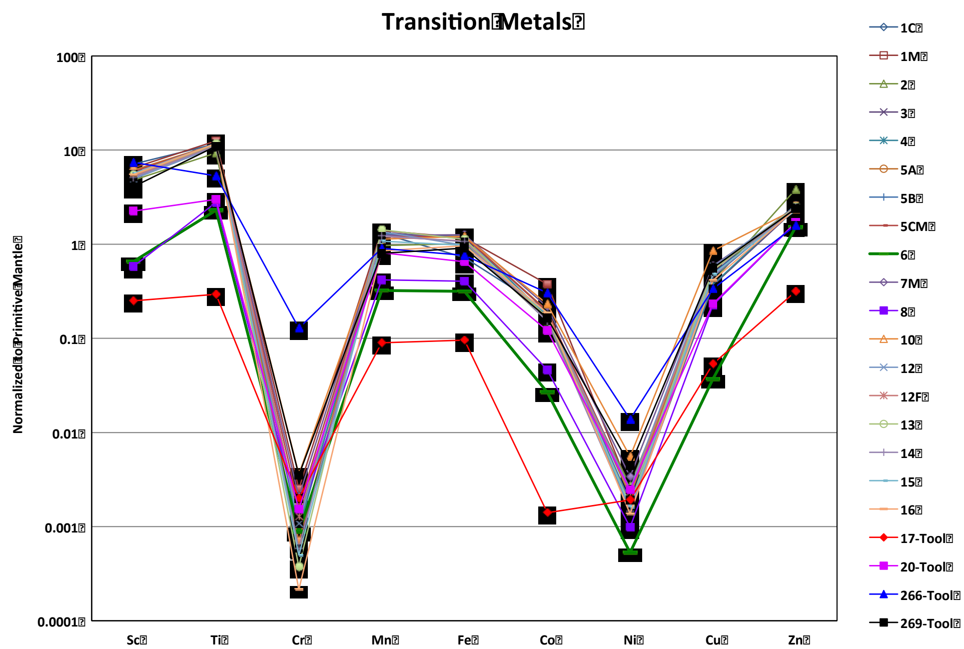


Figure 14 – Transition metals normalized to the Primitive Mantle of McDonough (1992).

5.2 Discrimination Diagrams

Figure 15, a tectonic discrimination diagram based on the ratios of Zr/Ti versus Nb/Y, further illustrates the composition of the dike samples and artifacts. Most of the dike samples plotted as basalts. Dike samples 6 and 8 were classified as alkali basalts. Alkali basalts are given a separate classification, because they contain above average amounts of potassium and sodium than most basalts. The chemical average of artifact 269 plots into the basalt classification, artifact 17 is a trachyte, which is a porphyritic extrusive rock made of alkali feldspar and mafic minerals such as biotite, hornblende or pyroxene as the main components. Artifact 266 did not fall within the boundaries of the tectonic discrimination plot, because it is extremely deficient in Zr.

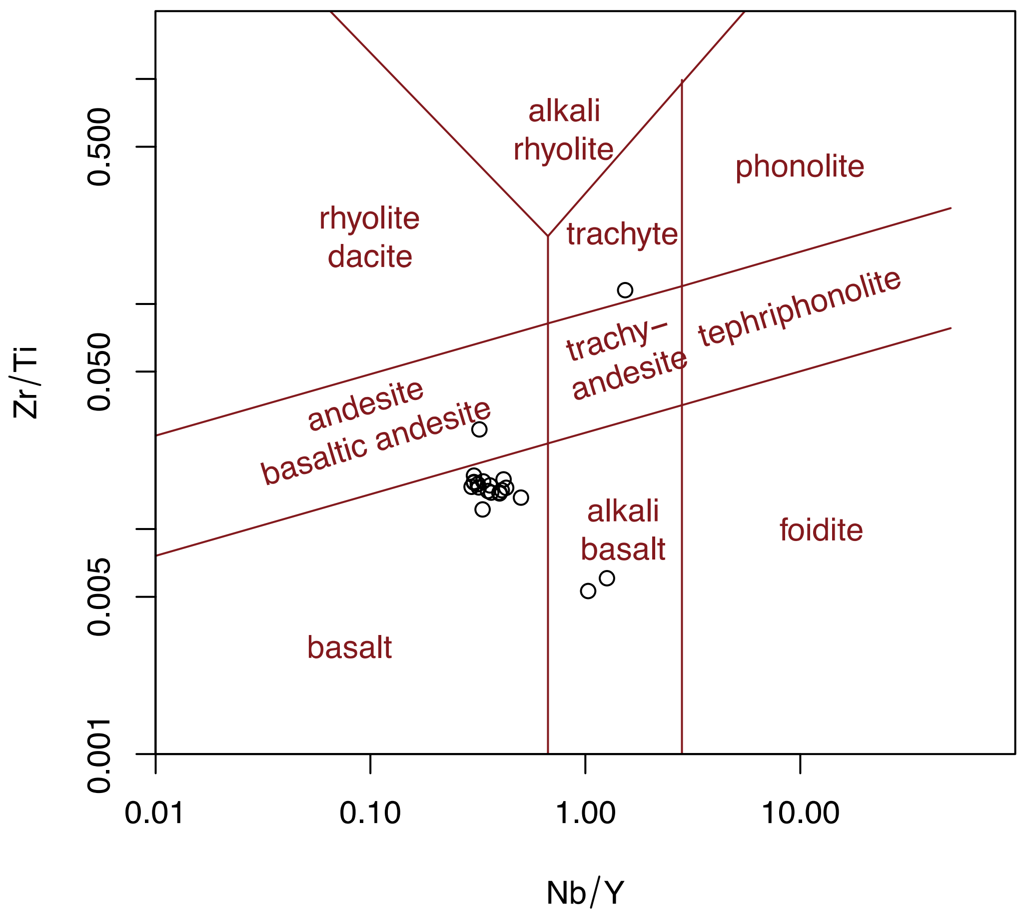


Figure 15 - Tectonic discrimination diagram plotting Zr/Ti versus Nb/Y based on Pearce (1996).

On a QAPF (quartz-alkali feldspar-plagioclase feldspar) diagram (Fig. 16), artifact 266 plotted as an alkali-feldspar trachyte, which is higher in Na_2O and K_2O bearing feldspars and has little to no quartz. Artifact 20 plotted as a trachyte, a feldspar rich aphanitic to aphanitic-porphyritic rock in which more than two-thirds of the feldspar is alkali feldspar, usually sanidine, accessory minerals may be biotite, augite, and magnetite.

Dike sample 13 is classified on the QAPF as a latite, which is intermediate between a trachyte and andesite, in which the two feldspars occur in sub-equal amounts. Three samples, artifact 17 and dike samples 6 and 8 are classified as dacite, although the latter two are in a boundary between dacite and the basalt-andesite classifications. The remainder of the samples fell between the categories of quartz-alkali-feldspar trachyte and basalt-andesite.

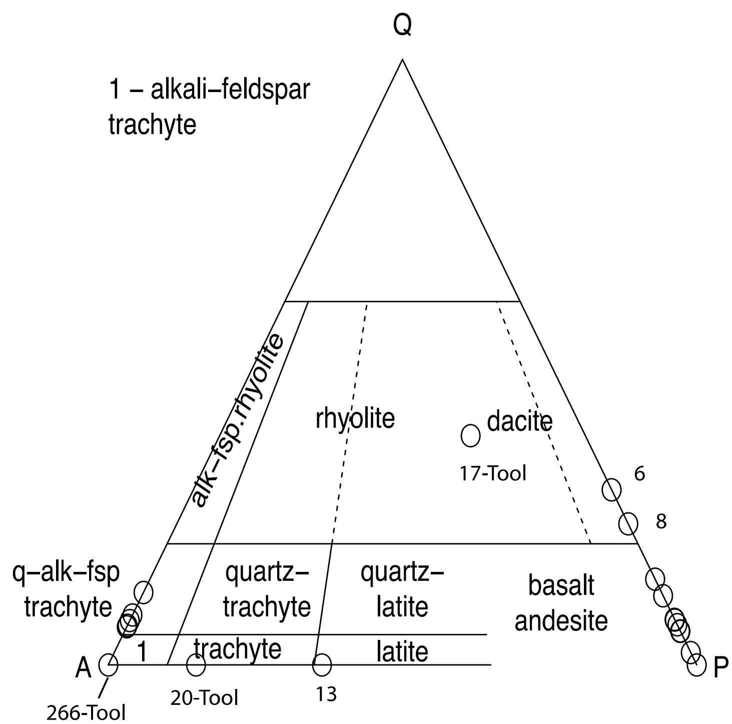


Figure 16 - QAPF diagram based on Streckeisen (1978).

5.3 Petrography

All of the samples collected from the dikes were made into thin sections, as were samples taken from the stone artifacts. See Appendix A for photographs of all of the thin sections. This section will examine the texture and structures of the dike samples and the stone tools (lithic artifacts). All of the dike samples contain magnetite with concentrations ranging from 1% wt.-21% wt. The heavy concentration of magnetite made it nearly impossible to take the dike trend directions with a brunton compass.

Figure 17 is a collage of views of the dike samples 6 and 8 in thin section. These show a typical porphyritic texture. The grain size in these samples were some of the largest at ~5mm -1mm in size making them phaneritic. Zoned plagioclase phenocrysts with a combination of discontinuous, oscillatory and convolute zoning can be seen (Fig. 17A and B). Undulose extinction is indicative that the rocks have been strained (MacKenzie and Adams, 1994). In Figure 17 A and B, we also see in the top middle what appears to be a hornblende phenocryst mostly enclosed in magnetite. These and other phenocrysts are embedded in a fine-grained groundmass giving it a holocrystalline-porphyritic texture. Views C and D of Figure 17 (Dike sample 6) we see a microcline phenocryst with gridded twinning, and hornblende with opaque rims of magnetite in a hypocrystalline matrix giving it a hypcrystalline-porhyritic texture. The crystals in both of these samples range from euhedral to subhedral. Partially sericitized plagioglase crystals are visible in views A and B, which give them a grainy appearance. The large microcline crystal in views C and D also shows signs of sericitzation. These two samples are classified alkali basalt on the discrimination diagram (Fig. 15) and as dacite on the QAPF (Fig. 16). Dike samples 6 and 8 have very little magnetite (~1-1.25 wt. %), but enough to weakly attract a magnet. Because these two samples have low amounts of mafic minerals, they are of intermediate composition making them more likely a dacite than basalt.

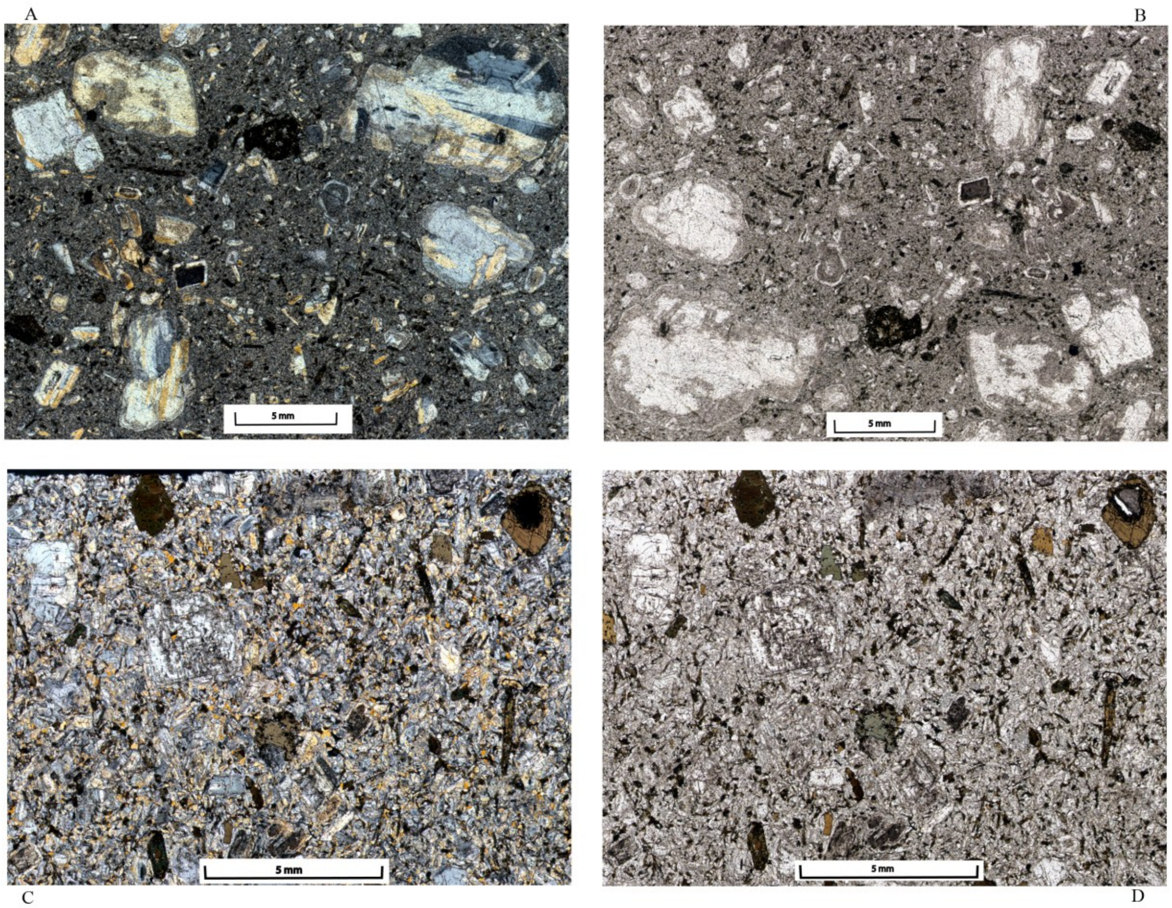


Figure 17 – Views A and B are views of sample 8. A is under crossed polars (xn) and view B is under plain polarized light (ppl). Zoning is evident in the large plagioclase crystals in views A and B. In addition the plagioclase crystal in the upper left corner is partially sericitized giving it a grainy appearance. Dike sample 6 is shown in views C (xn) and D (ppl). In these views, there is a large microcline crystal with gridded twinning as well as hornblende rimmed with magnetite. Photos by Dr. Jim Murowchick

In Figure 18 we can see the effects of more rapid cooling of the melt, much smaller mean grain size in the groundmass of glass. Euhedral to subhedral phenocrysts of augite, plagioclase, and lathes of sanidine with Carlsbad twinning are seen in the samples. As with the dike samples described earlier, the plagioclase is sericitized. No quartz was seen. The dike samples picture here, 1M, 2, 3, and 10 and others like them (1C, 13,) have a high content of magnetite making them highly magnetic. The combination of augite and magnetie (~20 wt.% and ~5 wt. % respectively) give these samples their mafic color. Based on the thin section analysis, these samples are hypocrystalline basalt.

Dike samples 15 and 16 (Fig. 19) are very similar in composition (Table 5). Lathes sanidine and phenocryst of anorthoclase are found in both samples. Heavy alteration of feldspars has left pseudomorphs, probably the result of hydrothermal activity (Murowchick, pers. comm., 2011). The grains of feldspars and augite are euhedral to anhedral and the magnetite is coarse with dendrites throughout all embedded in a glassy hypocrystalline groundmass.

Dike samples 12F and 14 (Fig. 20) are examples of an aphanitic texture. There are a few visible phenocrysts of sanidine (the slender lathes) and augite in both samples. The augite is recognizable by its second order interference colors under crossed polars (views A and C). In views A and B (dike sample 12F) there are three large spherical phenocrysts of pyrite.

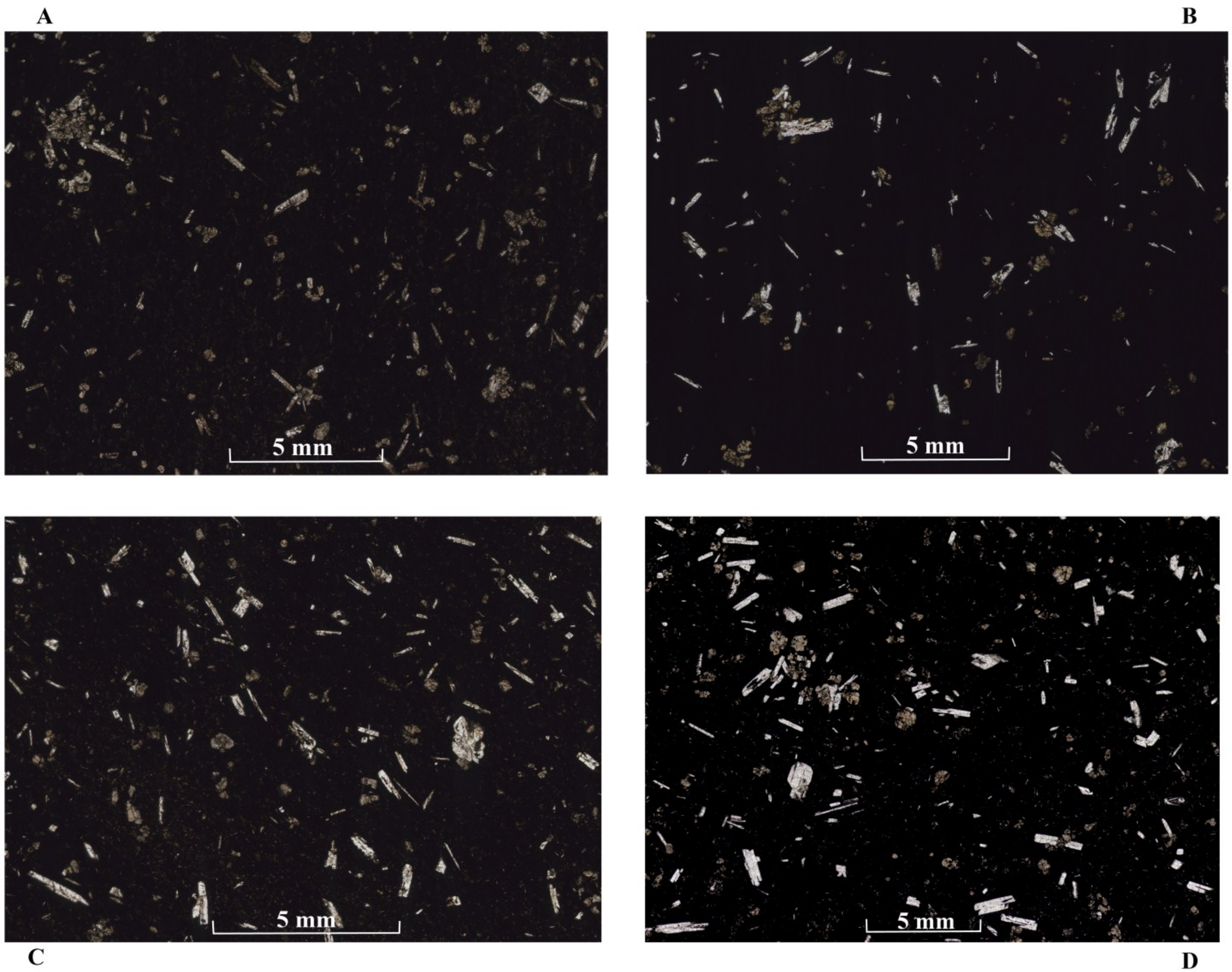


Figure 18 – Photos of thin section slides of dike samples 2, 3, 4 and 10. The porphyritic texture shown in these thin sections is typical of most of the dike samples. The grains are euhedral to subhedral and are enclosed in a fine-grained groundmass.

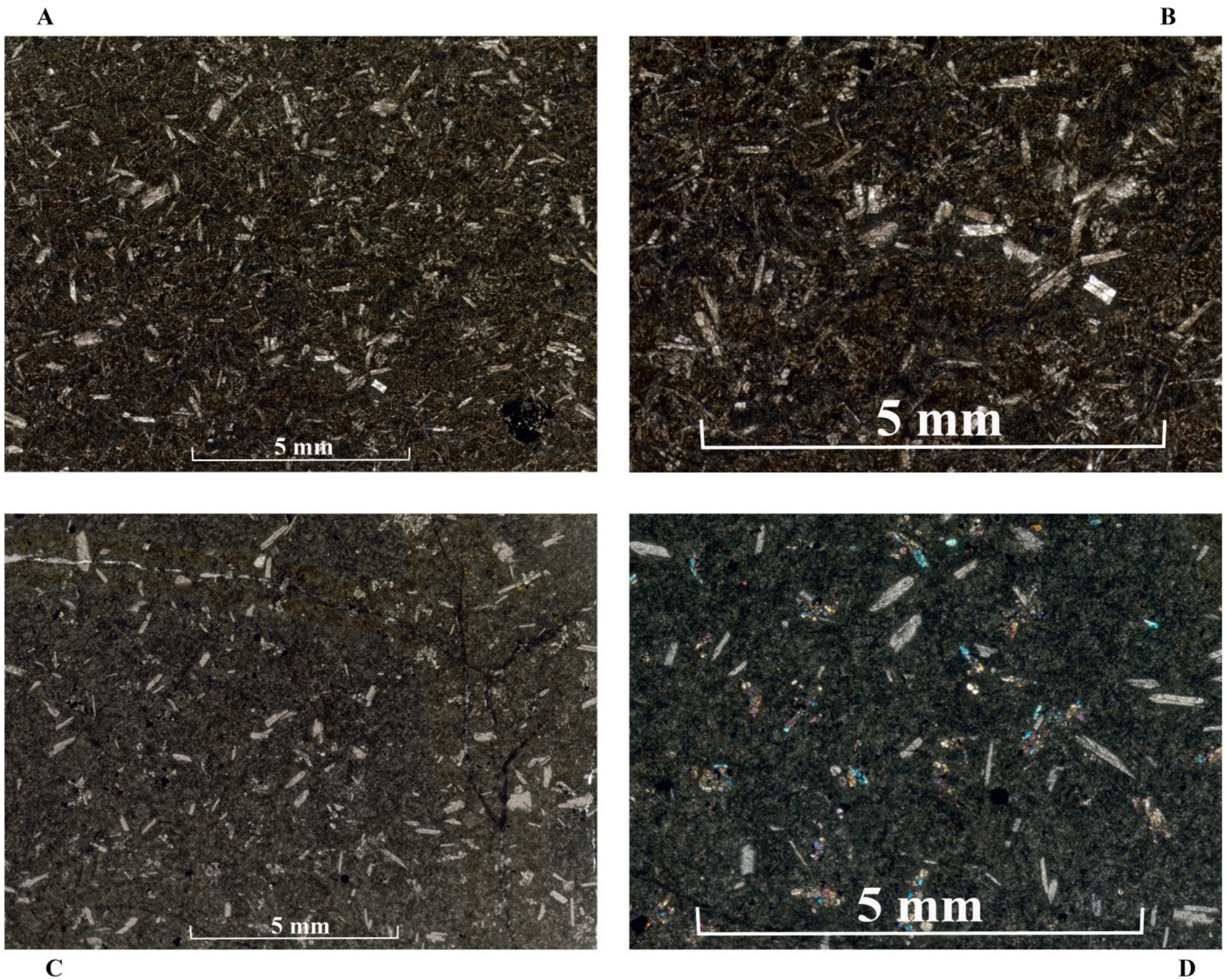


Figure 19 – Dike samples 15 (views A and B) and 16 (views C and D). Like the other dike samples, these are porphyritic. The crystals are euhedral to subhedral and grain size ranges ~1mm - < 0.5mm. Notice the alteration halo in view C running along the top of the view.

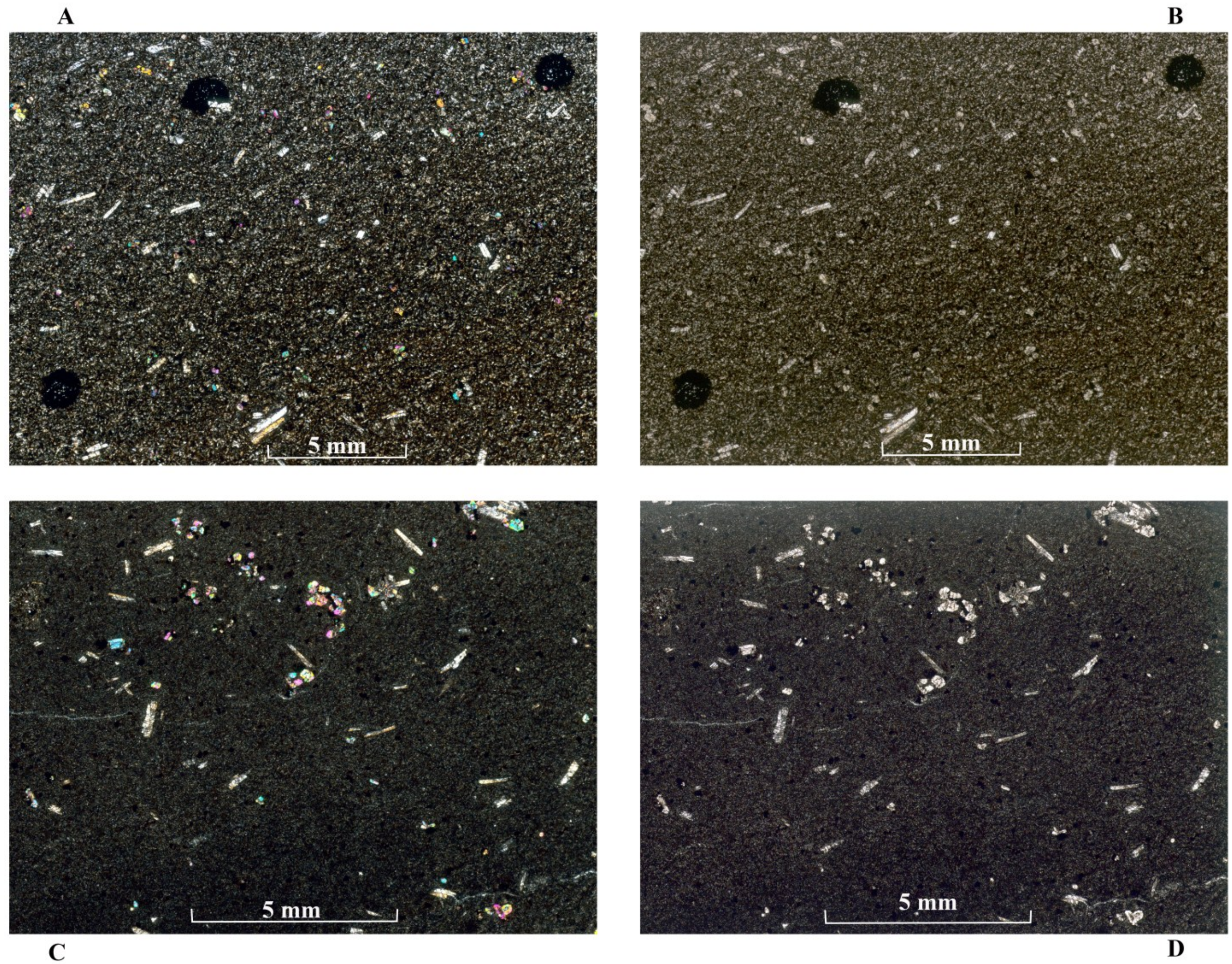


Figure 20 – Dike sample 12F (views A xn and B ppl) and dike sample 14 (views C xn and B ppl). The three large black circles seen in views A and B are pyrite globules.

Tool17 (Fig. 21) is composed mainly of plagioclase feldspar and quartz with some augite present. Although plagioclase is present, no identifiable crystals could be found in the thin section. The rounded crystals visible in views A and B are corroded quartz cystals in a fine-grained groundmass. On the discrimination diagram (Fig. 15), tool 17 is classified as a trachy-andesite and as a dacite on the QAPF (Fig. 16). Trachyandesite are rocks that have silca content at or below what an andesite normally has, and greater than 7% alkali feldspars (Raymond, 2002). Dacites could be considered a trachyandesite based on this definition.

Tool 20 in views C and D (Fig. 21) is a porphyritic rock, which has euhedral phenocrysts of sanidine and plagioclase exhibiting zoning. A sanidine crystal in the upper right field of view is an example of Carlsbad twinning, which distinguishes them from plagioclases that normally have lamellar twinning (MacKenzie, 1980). A few crystals of augite can be seen near the center of the field of view. In the lower portion there is a phenocryst of orthopyroxene. Tool 20 was classified as an andesite/basaltic andesite on the discrimination diagram (Fig. 15) and as a trachyte on the QAPF (Fig. 16). Based on the thin section, a trachyandesite classification is substantiated.

Tool 266 (Fig. 22 views A and B) is composed of hornblende and anorthoclase according to the XRD analysis of Rock Jock 7. The interference colors under crossed polars show fairly high first order interference colors, which make it appear more likely augite or titanaugite. If it were hornblende, which was identified in Rock Jock, lower first order colors would be expected. The opaque mineral seen throughout the specimen is magnetite. The crystals vary from euhedral to anhedral.

Figure 23 is a collage showing magnetite dendrites, with reticular intergrowths, which were seen throughout the dike samples. Of the artifacts, only tools 17 and 269 contained the magnetite dendrites (Fig. 24). Tool 20, has about as much magnetite (2.80 wt. %) as tool 269, but no dendrites. Tools 17 and 266 have so little magnetite that when doing compositional analysis, none was detected (Table 5). Another point of interest is that much of the magnetite is skeletal (irregular or not fully developed crystal form). This type of crystal growth and dendritic crystal growth are favored when the magma is undercooled (Raymond, 2002). Some of the magnetite found in the dike samples and tool 269 had visible lamellae containing the mineral ilmenite (Fig. 25). Ilmenite can be distinguished from the magnetite by its lower reflectivity under transmitted light.

Plagioclase often alters to a fine-grained micaceous material called sericite (Philpotts, 2003). Sometimes the alteration is incipient, other times it may consume the entire mineral resulting in pseudomorphs. Alteration is evident in much of the plagioclase in the dike and artifact samples (Fig. 26). Notice the fine-grained dark material on the grains in the photo (in both ppl and xn light). Pseudomorphs are also present (views C and D) and are most likely the result of hydrothermal activity. Zoning of plagioclase is common in most of the dike thin sections (Fig. 27). Normal zoning results when calcium content decreases due to dropping temperature of the melt resulting in a sodic rim, whereas a calcic rim is reverse zoning. Some augite phenocrysts such as the one in Figure 27 (views A and B) exhibit zoning also. Both augite and plagioclase phenocrysts show a combination of discontinuous, oscillatory and convolute zoning. Undulose extinction is indicative that the rocks have been strained (MacKenzie and Adams, 1994).

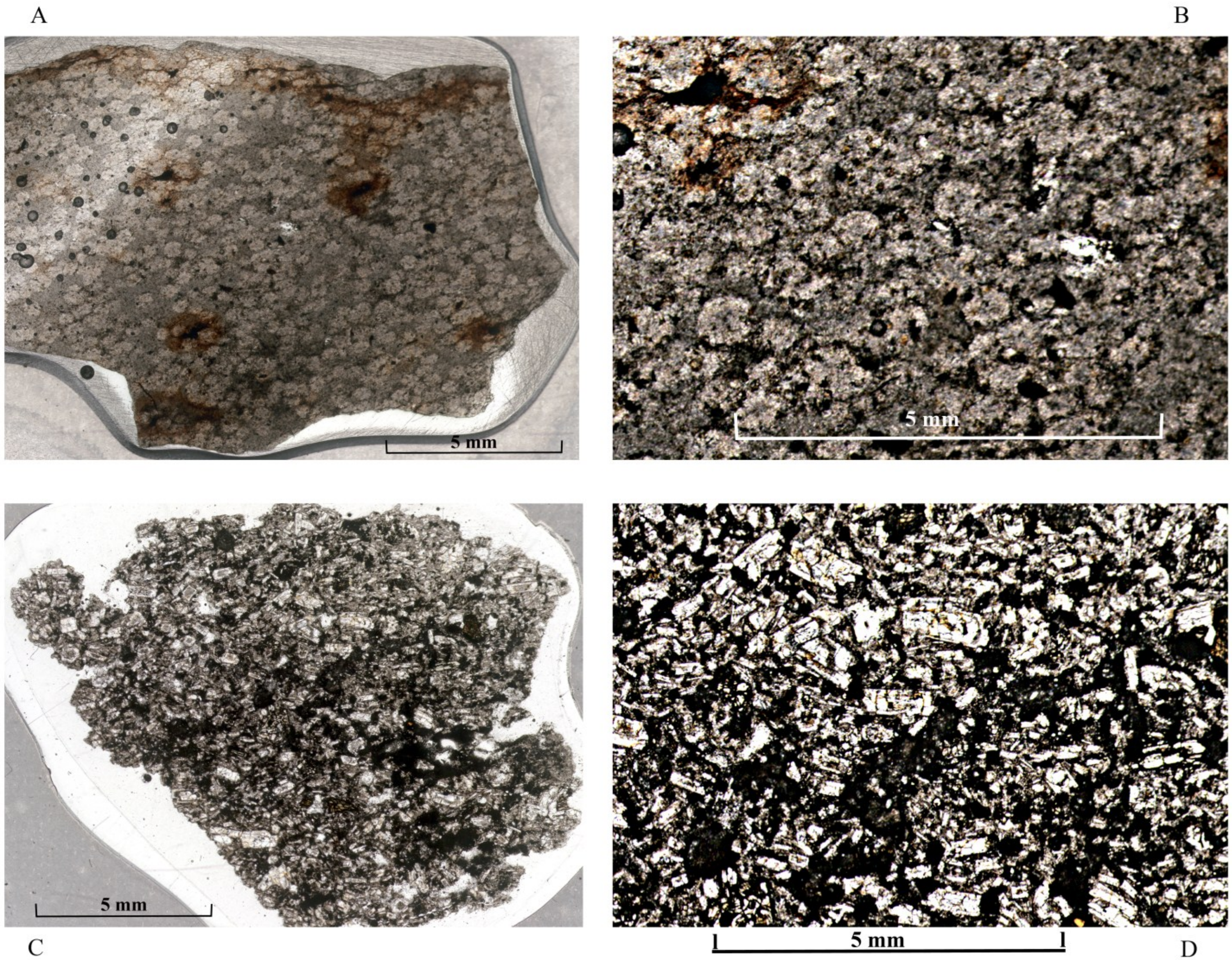


Figure 21 – Tool 17 is pictured in views A and B. It is holocrystalline with an ophitic texture. Tool 20 in views C and D has an intergranular texture.

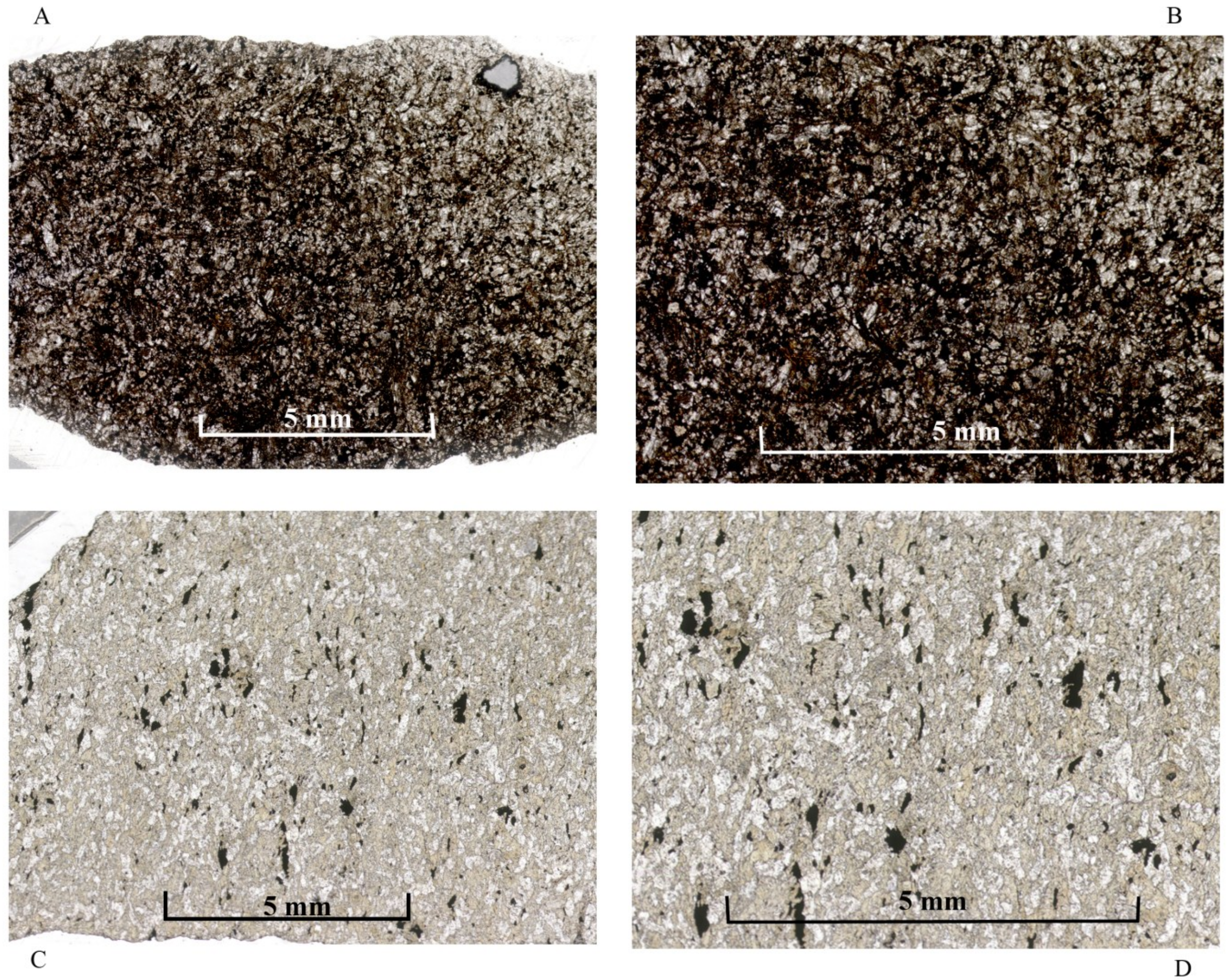


Figure 22 – Tool 269 in views A and B is hypocrystalline with phenocrysts of plagioclase, augite and magnetite. Tool 266 (views C and D) is fine-grained gabbro containing plagioclase, orthopyroxene, augite and magnetite.

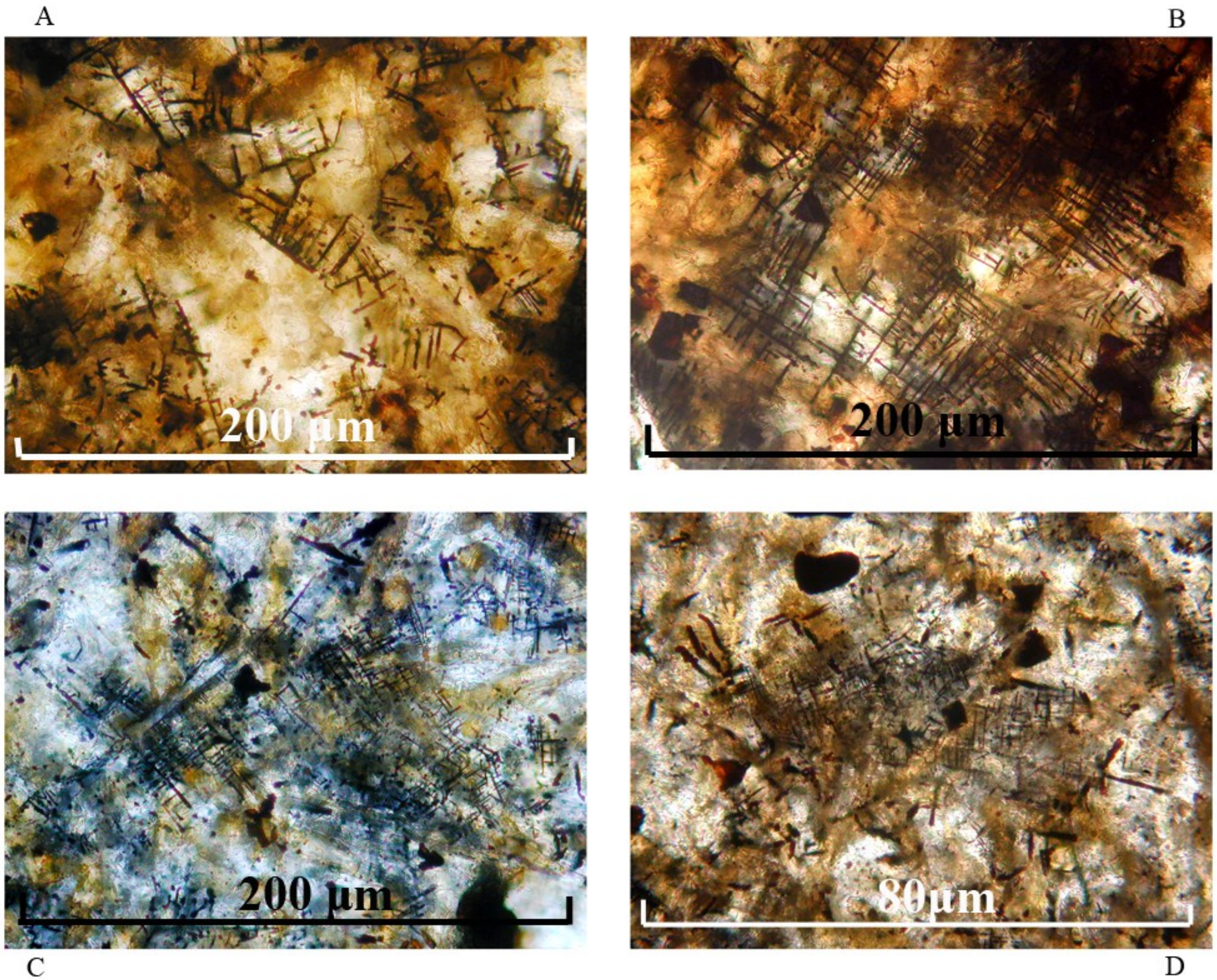


Figure 23 – Magnetite dendrites found in dike samples 1M (view A), 2 (view B), 6 (view D) and 10 (view D). Dendritic magnetite was in all of the dike samples, but was only found in the artifact, tool 269. Some magnetite was present in the other artifacts, but not the dendrites. Photos taken under plane polarized lighting.

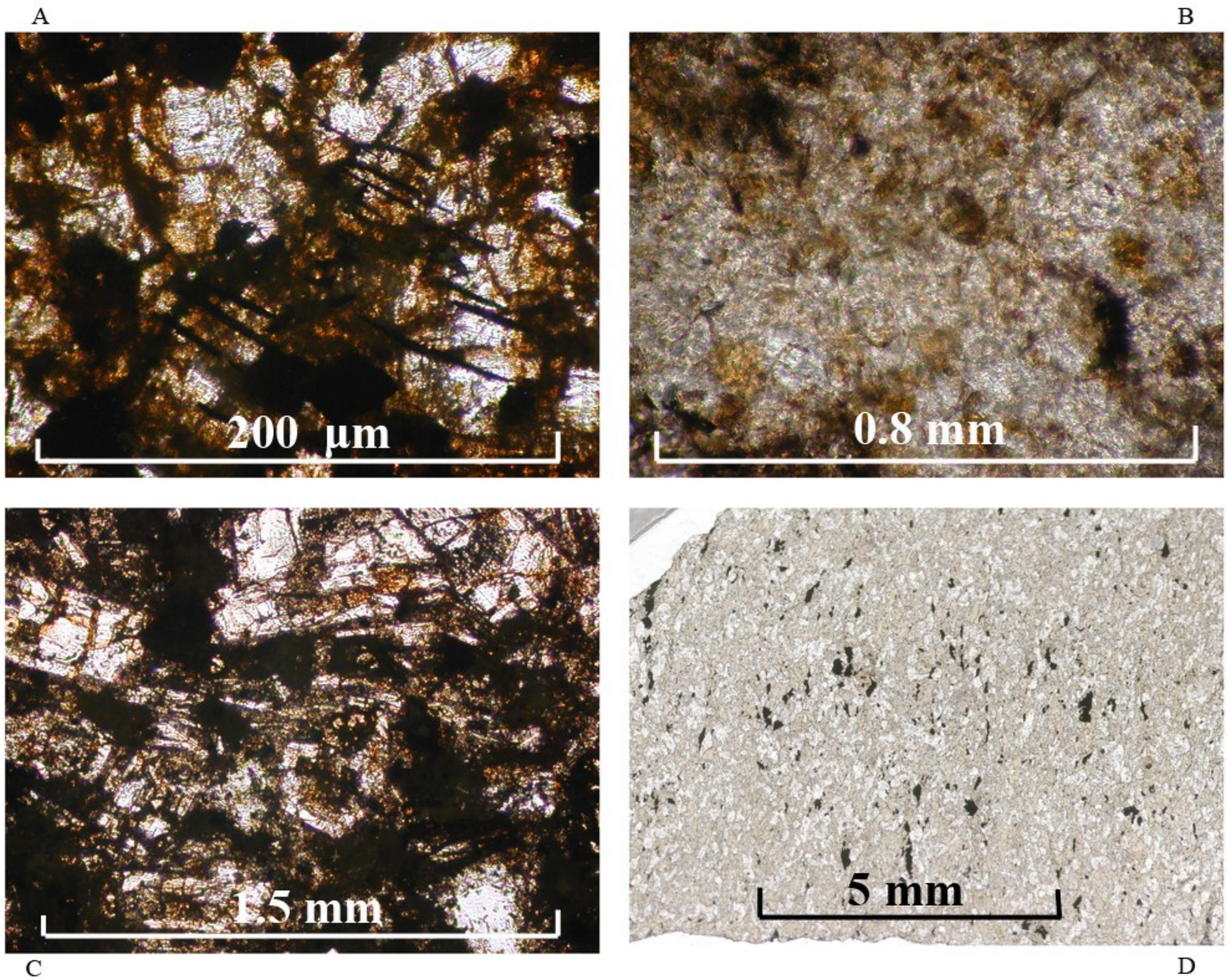


Figure 24 – Magnetite dendrites in artifact tool 269 (view A). Tool 17 in view B a few grains of magnetite, but no dendrites. Although tool 20 (view C) has magnetite throughout no dendrites were seen. View D is of tool 266.

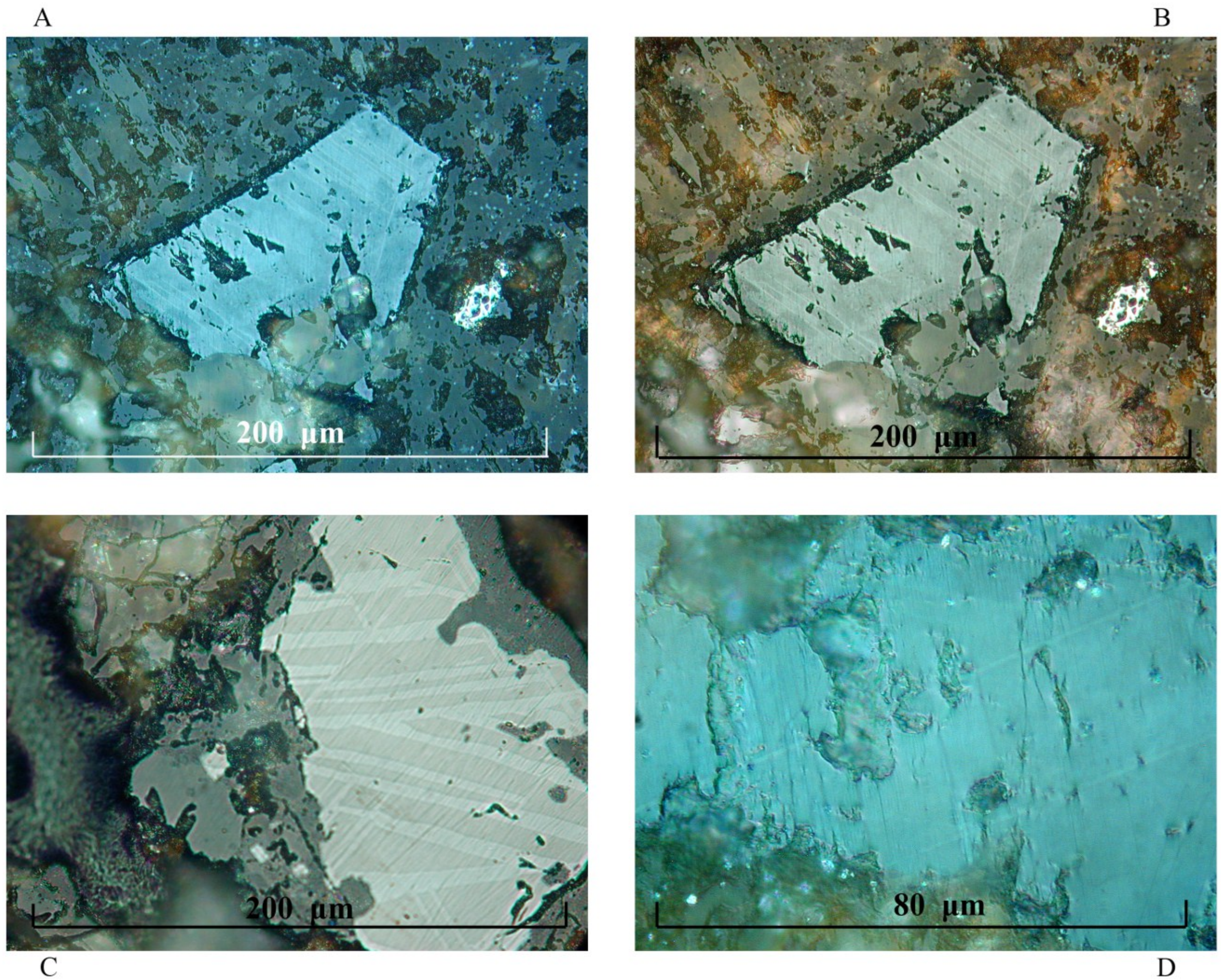


Figure 25 – Examples of magnetite with ilmenite lamellae. Ilmenite was found in many of the dike samples and in tool 269. Views A and D taken in reflected polarized light with slightly uncrossed polarizers. Views B and C taken in plane polarized reflected light.

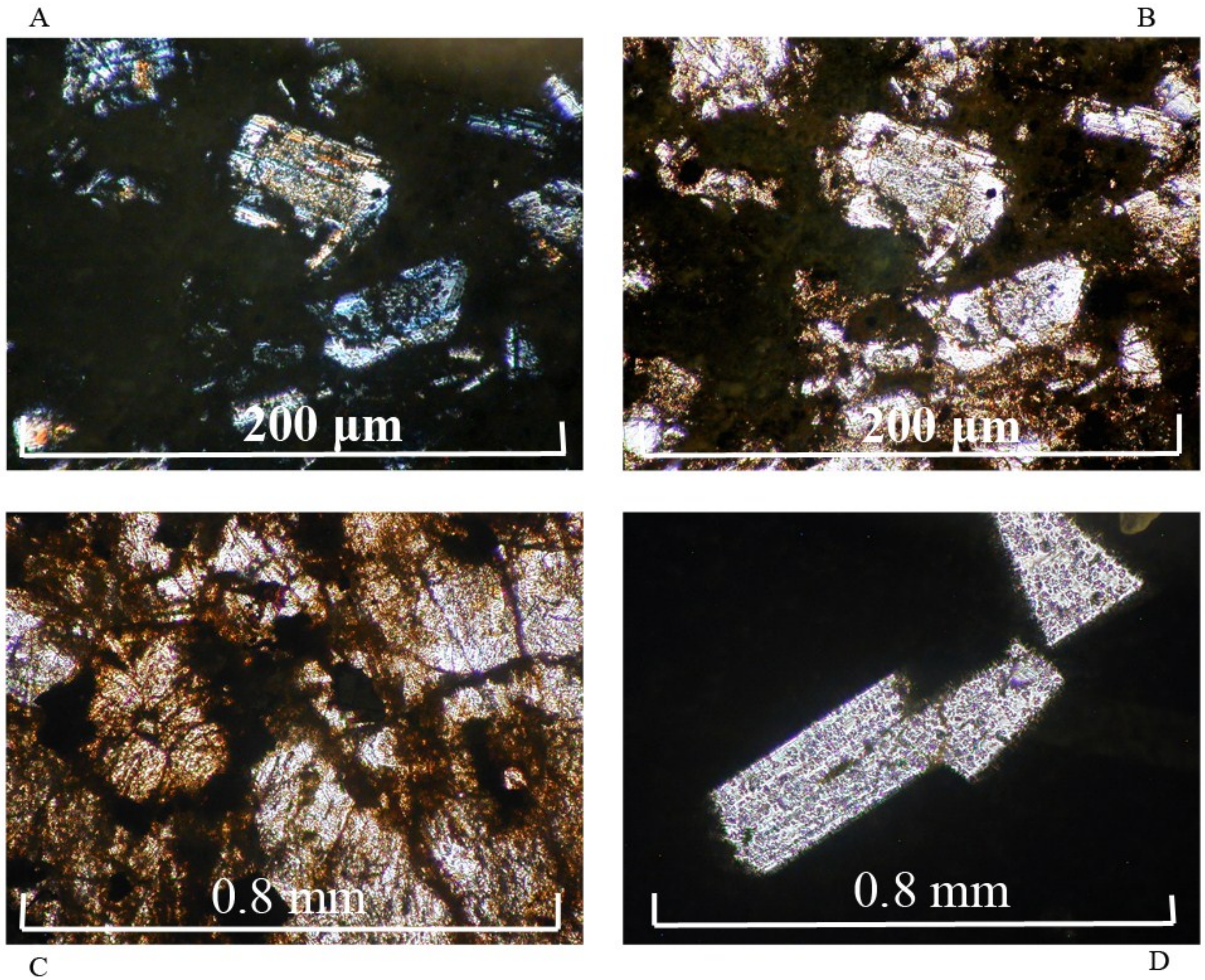


Figure 26 – These views illustrate various stages of alteration. The top two views show the grainy appearance of plagioclase with alteration. The field of view is ~1.5 mm. In view C magnetite can be see growing around an augite crystal in the mid left. Below that in the lower left corner is augite with heavy alteration. View D is a heavily altered plagioclase.

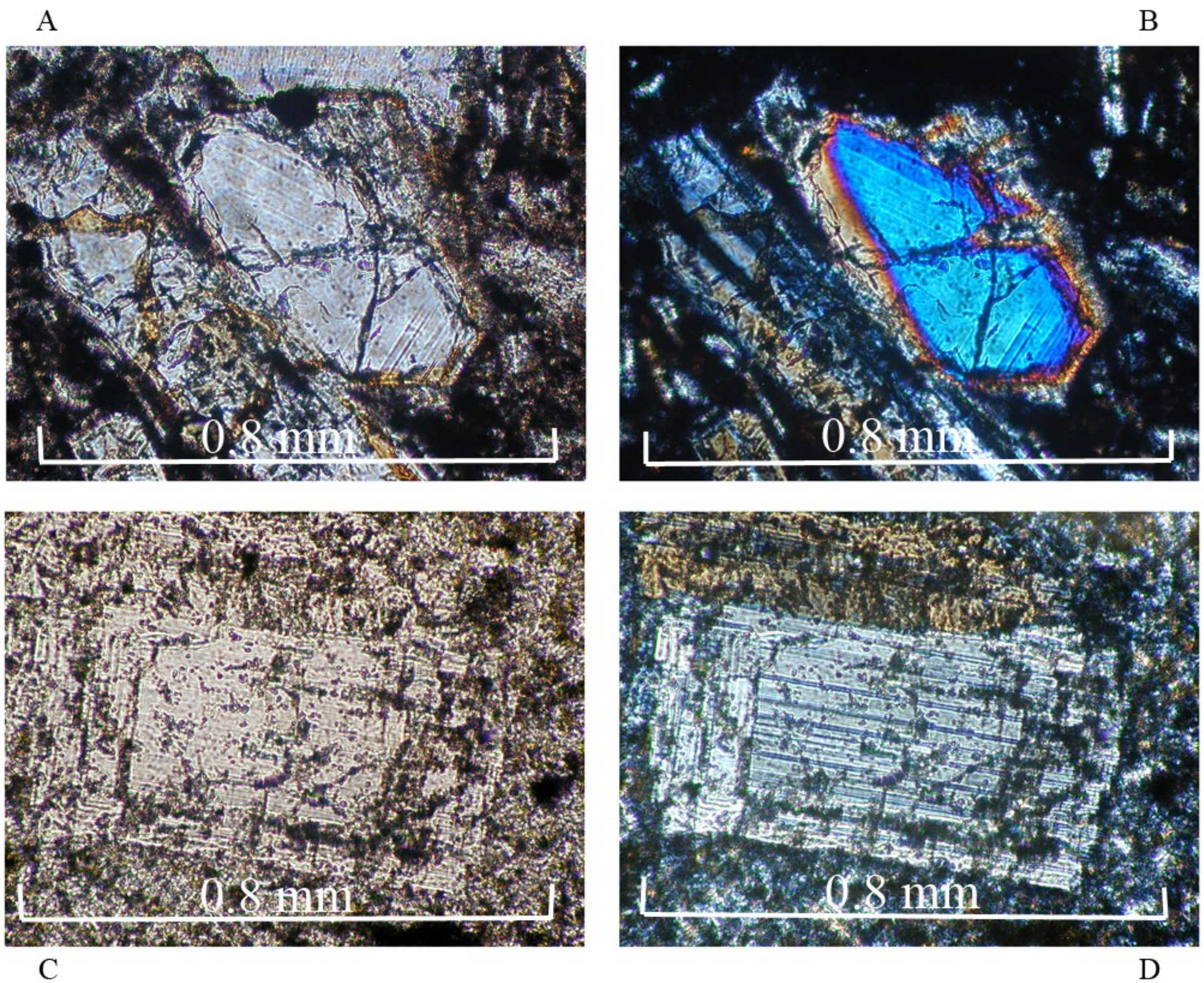


Figure 27 – Augite crystal with zoning is shown in views A (ppl) and B (xn). Alteration is visible around the outer rim. Another example of zoning is illustrated by the plagioclase crystal in views C (ppl) and D xn). Alteration can be seen in the orthoclase crystal directly above the plagioclase.

CHAPTER 6

DISCUSSION AND CONCLUSIONS

We know from historic accounts the Pericú were hunter-gatherer inhabitants of the Baja Peninsula (Mathes, 1975). According to these early accounts by Spanish explorers and priests, these people were seasonally mobile, breaking into small subsistence units and forage for food, water, firewood and tool making materials (Carmean, 1995; Toohey, 2005). Toohey writes

> During periods of population dispersion, specified activity groups would visit "logistical use sites" (Carmean 1994:45), such as Taller de San José.

San Pablo canyon is the location of La Piedra Pintada archaeological site, which was used by prehistoric natives. Other canyons in the near vicinity, such as San Dionisio, also have habitation sites (Carmean, 1994). Carmean proposed that large sites such as those in San Dionisio canyon were used for large seasonal gatherings and smaller sites in that canyon and other nearby smaller canyons, like San Pablo, were more permanent camps. It is not known whether La Piedra Pintada was a permanent or logistical/seasonal camp.

Since the natives had no metal until European contact, most of their cutting tools were made of stone, particularly stone that produces conchoidal fractures (Andrefsky 1998; Odell 2004). The site could easily have been either, because it is located near a water source and food sources. In addition, there are a series of diabase dikes in the canyon, which could have been a source of material for the production of stone tools. Such material was found at La Piedra Pintada archaeological site.

The main question this thesis tried to answer is whether the natives used only locally available materials or did they transport some types of tool making stone. Four stone artifacts collected during the excavation were chosen for this project. The geochemical, mineralogical and petrology results reveal that all of the dikes but two (dikes 6 and 8) and tool 269 are very similar in concentrations of the elements analyzed, have the same general mineral composition, and have similar textures. This suggests that tool 269 was very likely fabricated from one of the dikes. Although its elemental trends are not as close as tool 269, tool 20 varies only slightly from the dikes. In addition, its mineralogy and petrology are similar to several of the dikes (12, 12F and 13), which lead me to believe that it is quite possibly from the canyon. Tools 17 and 266 are very different in their geochemical trends from those of the dikes, as well as in mineral composition and in thin section indicating that they are not from the dikes. These data make is unlikely that tools 17 and 266 are made from the dike material collected from San Pablo Canyon.

These results seem to support the expectation that these hunter-gatherer people brought some tool making material with them as well as used local material from the canyon (Carmean, 1994). Lithic studies have shown that if high quality local material is abundant, most artifacts will be made from the local material (Elliott, 1991; Andrefsky, 1994; Hunter, 2008). However, if usable material is not readily available, lithic procurement trips had to be made. Binford (1979) suggested that procurement may have taken place during the process of completing other tasks, similar to the strategy used by the Nunamiut, an Eskimo tribe.

> For example: a fishing party moves in to camp at Natvatrauk Lake. The days are very warm and fishing is slow, so some of the men may leave the others at the lake fishing while they visit a quarry on Nassaurak Mountain, 3.75 miles to the southeast. They gather some material there and take it up on top of the mountain to reduce it to

> transportable cores. While making the cores they watch over a vast area of the Anaktuvuk valley for game. If no game is sighted, they return to the fishing camp with the cores. If fishing remains poor, they return to the residential camp from which the party originated.

Others such as Gould (1985) suggest that mobile groups made specific trips to quarries, collecting material and transporting it elsewhere for reduction. A "ubiquitous" gray-green rhyolitic material was found throughout Cañon de San Dionísio, a site about 22.5 km away (Carmean, 1994; Toohey, 2007) lending support to collecting expeditions. Taller de San José, which is about 32 km from La Piedra Pintada near Santa Catarina, is an example where material was collected and transported elsewhere for further processing (Toohey, 2007).

Although proximity/availability of suitable raw material was important, the quality of the raw materials was also an important factor to many prehistoric foraging populations especially in the production of ritual artifacts (Andrefsky, 1994). Studies have suggested that hunter-gatherers recognized the variations in quality of the raw material and sought material suited to the task of the tool Andrefsky, 1994).

Archaeological research has advanced in recent years in the Cape Region of the Baja California Peninsula (Fujita, 2006; Carmean, 1995; Rosales and Fujita 2000; Fujita et al. 2002; Gonzales-Jose et al. 2003), however, more research is needed particularly in the canyon and mountain region, because it is still relatively unknown (Fujita 2006). The region has potential for provenance research, particularly with the discovery of quarry sites; such as Taller de San Jose located approximately 31.5 km from San Pablo Canyon (Toohey, 2007). Further geochemical and mineralogical analyses of material from other archaeological sites or nearby quarries is needed to identify patterns of travel of these hunter-gatherers to obtain natural resources for food and tool making.

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