Miocene Geologic History of Eastern Santa Catalina Island, California

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Abstract – Field relations show that the Santa Catalina Island pluton intruded both the Catalina Schist and the San Onofre Breccia. Early to middle Miocene macrofossils from the San Onofre Breccia of East End Quarry support the 19 Ma radiometric age of the pluton and show that the San Onofre Breccia of East End Quarry is one of the oldest known exposures of that formation. The pluton includes about 50% subvertical sheeted dikes. We believe that the pluton was initially emplaced into a rhombochasm-like opening along a transtensional fault segment that separated the Catalina Schist from the San Onofre Breccia. Present exposures represent a moderately shallow level of the intrusion. West of Silver Canyon, map relations and several outcrops show that the pluton overlies the Catalina Schist along a low-angle fault.

Introduction

This report is the first to describe in detail the structure of the Miocene hornblende quartz diorite pluton, and its relations to its country rocks, as we observed them over 35 man-days spent in the southeastern third of Santa Catalina Island (Fig. 1). Reasons for studying the pluton include the following: 1) it is the only known granitic intrusion into rocks traditionally ascribed to the Franciscan Complex; 2) the pluton has yielded 19 Ma K-Ar dates (Forman 1970; Vedder *et al.* 1979) that may be roughly coincident with (Engebretson *et al.* 1985) or shortly after (Atwater 1970; Atwater & Molnar 1973) the change from subduction to transform motion along this part of the plate boundary; 3) the pluton separates the Catalina Schist from the sedimentary sequence of East End Quarry, which includes the San Onofre Breccia (Vedder *et al.* 1979); 4) although Catalina Island lies in the middle of the Catalina terrane (Howell & Vedder 1981; Blake *et al.* 1982), pre-Miocene sedimentary rocks in the East End Quarry sequence probably correlate with far-distant strata outside the terrane, in the northern Nicolas, Malibu, and Santa Ana (Guerrero) terranes (Vedder *et al.* 1979; Blake *et al.* 1982); 5) the pluton shows a pronounced sheeted character where well exposed (Vedder *et al.* 1979); 6) the pluton contact with the Catalina Schist west of Silver Canyon parallels topographic contours (Smith 1897; Bailey 1941) and 7) xenoliths were reported to occur only in a belt between Avalon and the mouth of Silver Canyon and were said to consist only of lithologies of the Catalina Schist (Smith 1897; Vedder *et al.* 1979).

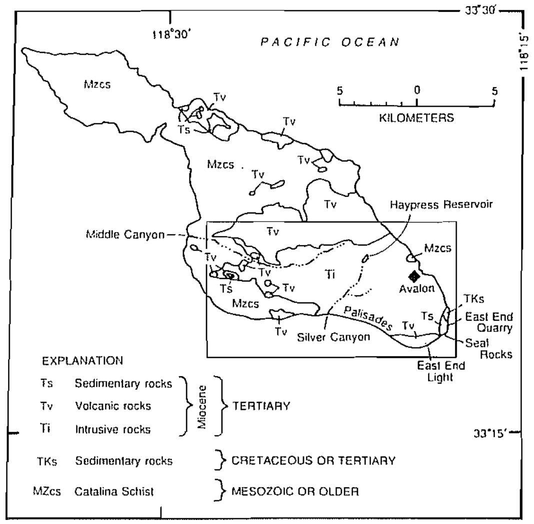

Figure 1. Generalized geologic map of Santa Catalina Island showing place names and location of large scale map. Geology modified from Smith (1897), Bailey (1941) and Vedder & co-authors (1979).

These observations suggested to us that a complicated series of magmatic and tectonic events had affected the southeastern part of Santa Catalina Island during Miocene and later time. Our purpose in undertaking this research was to provide a more complete picture of the geologic evolution of this part of the California Continental Borderland.

Pluton Lithology and Structure

The Miocene intrusive body on the southeastern third of Santa Catalina Island has been described as a laccolite (Smith 1897), stock (Bailey 1941), pluton (Forman 1970), or stock-like mass (Vedder *et al.* 1979). None of these terms accommodates all the observable features of the body. The most important characteristic is its sheeted structure (Fig. 2). Where well exposed, the body appears to be at least 50% dikes, and the attitude of overlying volcanic rocks suggests that the dikes were emplaced subvertically. In this paper, we will refer to the whole body as a pluton by invoking the broader definition of the term, acknowledging that the diapiric character commonly connoted is rarely visible on Santa Catalina Island.

Smith (1897) described the pluton as a (biotite-), (augite-) and hornblende-bearing banatitic porphyrite— an obsolete term for porphyritic (biotite)-(augite)-hornblende quartz diorite. He recognized different dikes as varying in content and composition of mafic minerals, in quartz content and in texture.

The dikes are 1/2-7 m wide. Their faces are slightly hummocky rather than planar, and they are weakly chilled at the margins. The dikes are subparallel to each other, so that they cross in places. They trend predominantly north to northeast, although the trend ranges from northwest to east (Fig. 3). Igneous activity and coeval tectonism are indicated by brecciated shear zones that cross dikes and are intruded by other dikes. In another example, a fault breccia is entrained as a xenolith in a younger dike.

Northwest of a fault zone through the northwest wall of Silver Canyon and Haypress Reservoir (Fig. 3), some characteristics of the intrusion are different than the analogous characteristics to the soouthеast. The matrix tends to be finer grained in the northwest than in the southeast, and in places weathers to brilliant reds, golds and blues rather than buff. Poor exposure obscures the structure of the pluton, but discernible dikes persist for at least 1 km northwest of the fault. The most distinctive feature of the western part of the pluton is that it mostly lacks xenoliths, except for a possible one composed of amygdaloidal andesite and three closely spaced ones composed of albite-chlorite greenstone in and south of Middle Canyon.

Figure 4 shows the systematic variation of attitudes of dikes over the width of the pluton. Dikes in the Palisades dip at a moderate angle to the northwest. Dips increase to nearly vertical at the mouth of Silver Canyon and turn over to dip steeply southeastward farther north in the northwestern wall of Silver Canyon. Where exposed west of the fault through Haypress Reservoir, dikes consistently dip to the northwest. Based upon our observations, there are several alternative explanations for this structure. The first is simple antiformal folding of a typical swarm of parallel sheeted dikes, such as those in ophiolitic sections (Fig. 5). The second and third options begin with fractures in varying orientations which fill with magma; subsequent rifting propagates to form a zone that contains a high proportion of dikes (Fig. 6). The initial fracture patterns in these models are similar to the structures of the Comstock Lode in Nevada (Becker 1882) and downdropping around the Gulf of Mexico (Cloos 1971). Continuous exposures across the dike sequence illustrated in Figure 4 would be required to discriminate between a folding model and a faulting model. There are exceptions to these general dike attitudes that are shown in Figure 3. However, exposure is not complete enough to provide an explanation for these exceptions.

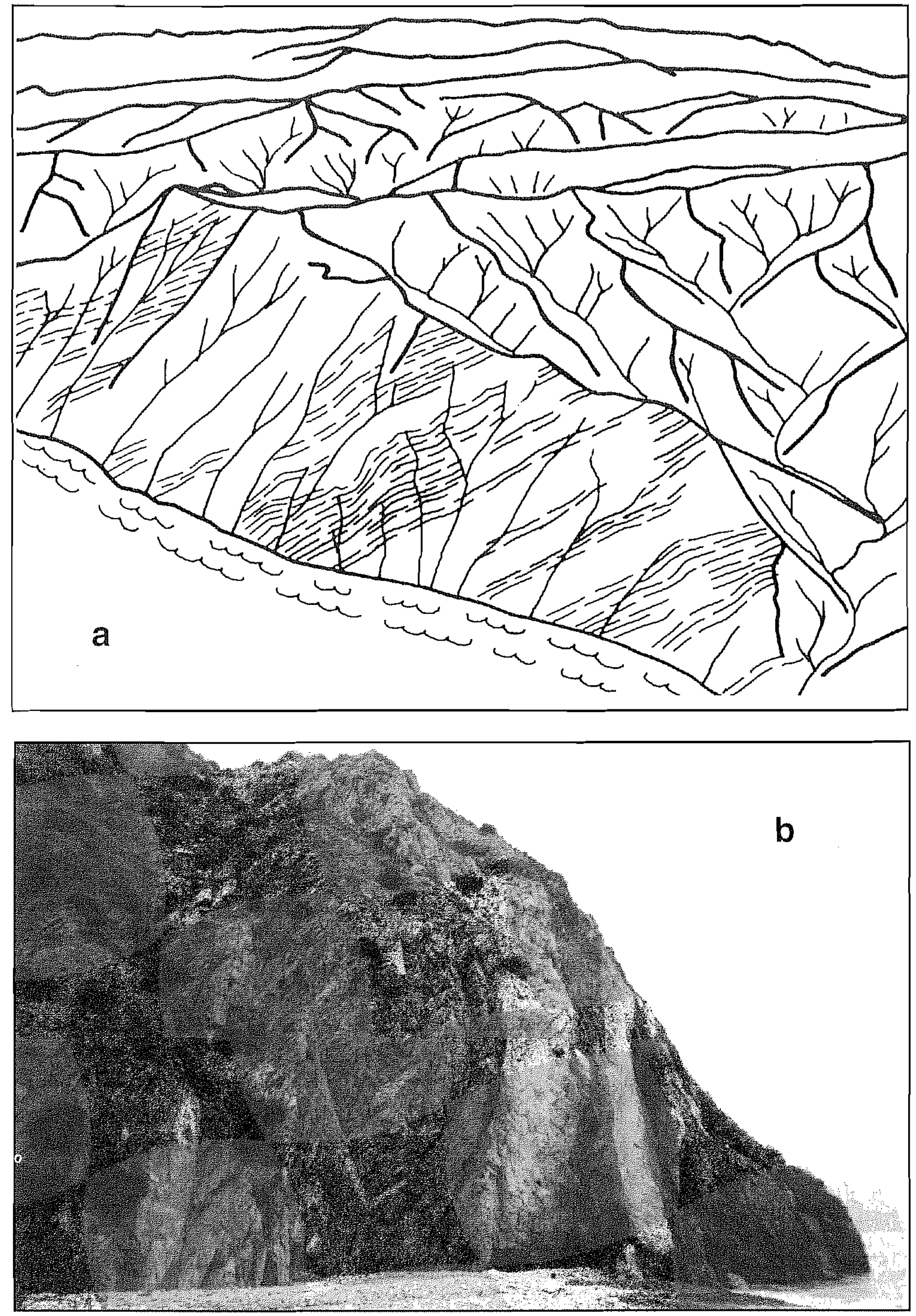

Figure 2. The sheeted nature of the pluton. a) Line drawing of photograph originally published by Shepard & co-authors (1939) showing dikes exposed along a 2.5 km segment of the Palisades near the southeastern end of the island. b) Steeply northwest-dipping dikes at mouth of Silver Canyon. Person in middleground for scale. Photographer is facing east.

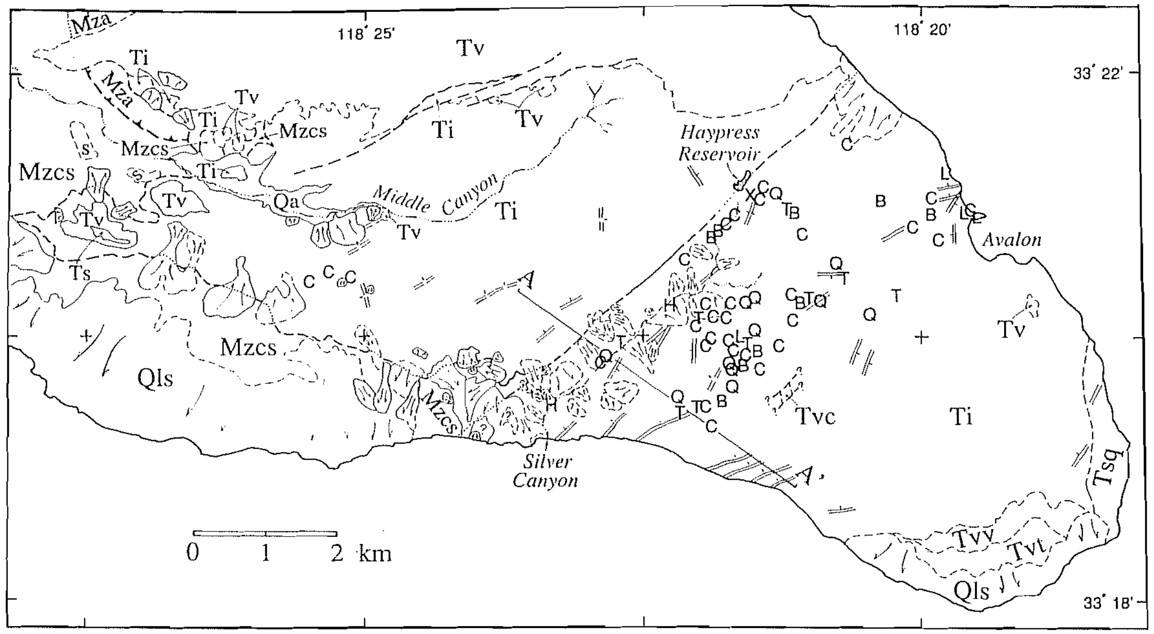

Figure 3. Generalized bedrock geology of the pluton and surrounding units, southeastern Santa Catalina Island. Light lines represent depositional or intrusive contacts, heavy lines represent faults, solid where exposed, dashed where approximately located, dotted where covered. Teeth on upper plate of thrust fault. Short parallel lines represent trends of steeply dipping dikes, or outcrops of dikes in Palisades; small ticks on the dike symbols represent the direction of dip. **Rock units: Ts**, Tertiary tuffaceous siltstone and calcarenite; **Tvc**, Tertiary volcaniclastic siltstones to conglomerates less than 19 Ma; **Tv**, Tertiary volcanic rocks 19-12 Ma, undifferentiated, mostly porphyritic and sometimes vesicular; **Tvf**, Tertiary andesitic flow rocks, frequently with asymmetric vesicles or amygdules; **Tvt**, Tertiary crystal-lithic-vitric andesitic tuff; **Ti**, Tertiary intrusive rocks— hypabyssal (biotite-)(augite-) hornblende quartz diorite porphyry; **Tsq**, Tertiary East End Quarry sequence, including San Onofre Breccia and underlying strata; **Mzcs**, Mesozoic or older Catalina Schist— greenschist and blueschist lithologies; **Mza**, Catalina Schist— garnet-hornblende amphibolite; **s**, serpentinite. **Xenoliths: B**, graphitic albite-biotite grayschist; **C**, albite-chlorite greenstone; **H**, garnet-hornblende amphibolite; **L**, lawsonite-talc-glaucophane blueschist; **Q**, vein quartz; **T**, actinolite-talc greenschist; **X**, San Onofre Breccia. For a description of rock types in the Catalina Schist, refer to Platt (1976). **A-A'**: line of schematic cross section shown in Figure 4. Geology significantly modified from Smith (1897), Bailey (1941) and Vedder & co-authors (1979). The new mapping is by S.Q. Boundy-Sanders (1986-87), J.G. Vedder (1986-87), C.O. Sanders (1986) and R.G. Bohannon (1987).

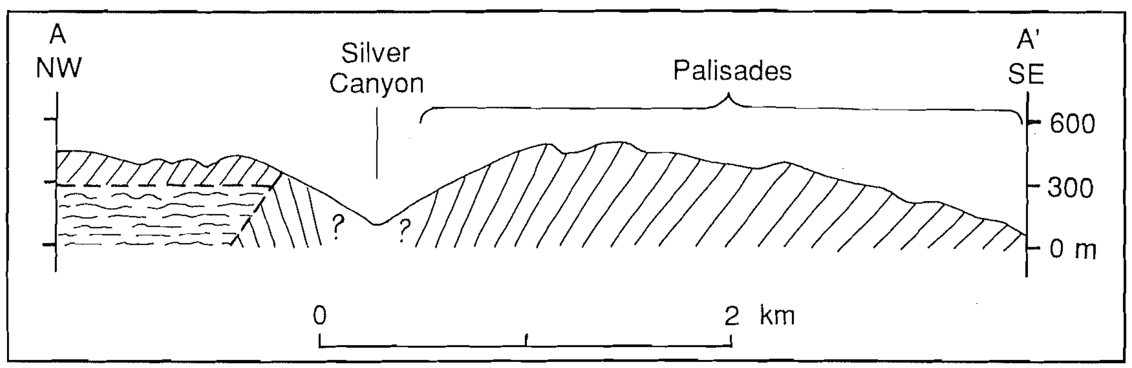

Figure 4. Schematic section across Silver Canyon and north of the Palisades, showing the general attitude of dikes and the most likely configuration of the contacts between the pluton and the Catalina Schist. No vertical exaggeration.

Volcanic Rocks

South of Avalon, the pluton is overlain by two rock types. One is a friable, maroon crystal-lithic-vitric tuff, mapped by Smith (1897) as andesite on the ridges north of East End Light. The other rock type overlying the intrusion is a siliceous, well-bedded, reworked, pale-green volcaniclastic sequence, which occurs as a 10 m thick road-cut exposure on the ridge south of Avalon. The thinnest beds, about 2-5 cm in thickness, are composed of massive to laminated volcaniclastic siltstone. The thickest beds are 50-80 cm in thickness and are composed of clast-supported breccia. The unit was apparently downdropped into its present position in several fault blocks. Both faults and bedding attitudes are components of a southeastward dip of the pluton and the volcanic rocks that might be remnants of its carapace.

Xenoliths

The pluton contains an uneven sprinkling of inclusions, previously described as consisting of several lithologies of the Catalina Schist and occurring along a band of exposures between Avalon and the mouth of Silver Canyon (Smith 1897; Vedder *et al.* 1979). Some inclusions are small, on the order of 1 m in diameter, and are clearly entrained in a single dike. These small inclusions are accurately described as xenoliths that have been carried from their original position by the magma. Many other blocks within the pluton are much larger— 10's-100's m in length. These are far too large to have been engulfed in a single dike. We interpret them as pendants or screens that may or may not have been cut off from the country rock by intrusion of subsequent dikes. For simplicity we refer to all non-dike rocks in the pluton as xenoliths.

Our geologic mapping in the pluton indicates different terminations for the xenolith belt along its northwestern and southeastern edges. The belt is truncated along its northwestern edge by a northeast-trending fault zone that passes through Haypress Reservoir and the northwest wall of Silver Canyon (Fig. 3). The southeastern edge of the belt is poorly defined for two possible reasons, which are: 1) that the belt represents an axis along which entrainment of xenoliths occurred (*e.g.*, Fig. 6), or 2) that xenoliths settled at a particular isostatic level that is exposed in the area of Silver Canyon and presumably dips to the southeast (Fig. 5). Xenoliths east or west of this belt are composed of hypabyssal rocks or breccias similar in composition to the pluton.

Xenoliths in the main belt are of three general types: 1) lithologies of the Catalina Schist that constitute the majority of the xenoliths; 2) dike material which was torn free by subsequent intrusions and 3) rare blocks of San Onofre Breccia of East End Quarry. Each of these xenolith types can be unambiguously associated with its protolith— clast by clast in the case of the San Onofre Breccia xenolith. Greenstone and grayschist xenoliths of the greenschist unit of the Catalina Schist are the most common and widespread. Two amphibolite xenoliths crop out in the bottom of Silver Canyon, in the lower part of its course. Blueschist xenoliths are mostly restricted to the area around Avalon; the largest xenolith in the pluton is glaucophane-talc schist, 300-400 m in diameter, northwest of Avalon (Fig. 3; symbol L). Xenoliths of vein quartz seem to be associated with greenschist xenoliths around Silver Canyon. The single xenolith we found which was composed of San Onofre Breccia lies just south of Haypress Reservoir (Fig. 3; symbol X), inexplicably located on the opposite side of the xenolith belt from its source in East End Quarry. It is enclosed in a sheet that evidently was a relatively late intrusion, because the same sheet contains another xenolith of brecciated plutonic material.

New Findings in East End Quarry

Exposures in East End Quarry have changed significantly due to quarry operations since its sedimentary section was last described by

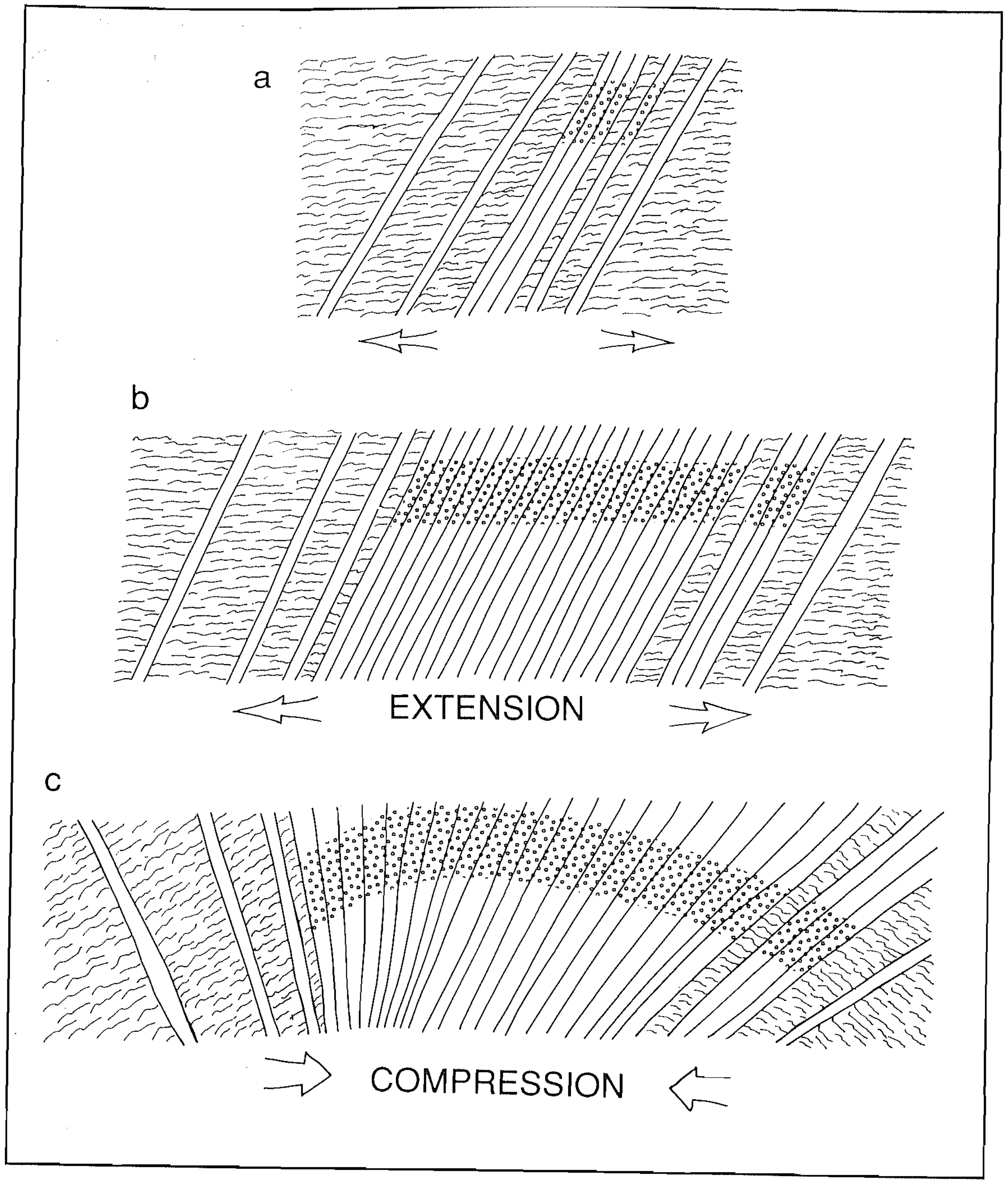

Figure 5. One model of extension that might produce a swarm of sheeted dikes. Open circles indicate zone that contains xenoliths; wavy lines, country rock; and parallel lines, dikes. a) Fractures nucleate in a single orientation, which is maintained by b) subsequent episodes of fracturing and intrusion. c) Later antiformal folding produces the change in attitudes of dikes over space. Xenoliths concentrate by isostasy at a particular level in the dikes. Vertical measurement of each panel is approximately 2-4 km. Foliation in the Catalina Schist is for illustrative purposes only; the schist in reality has a much more complex structure.

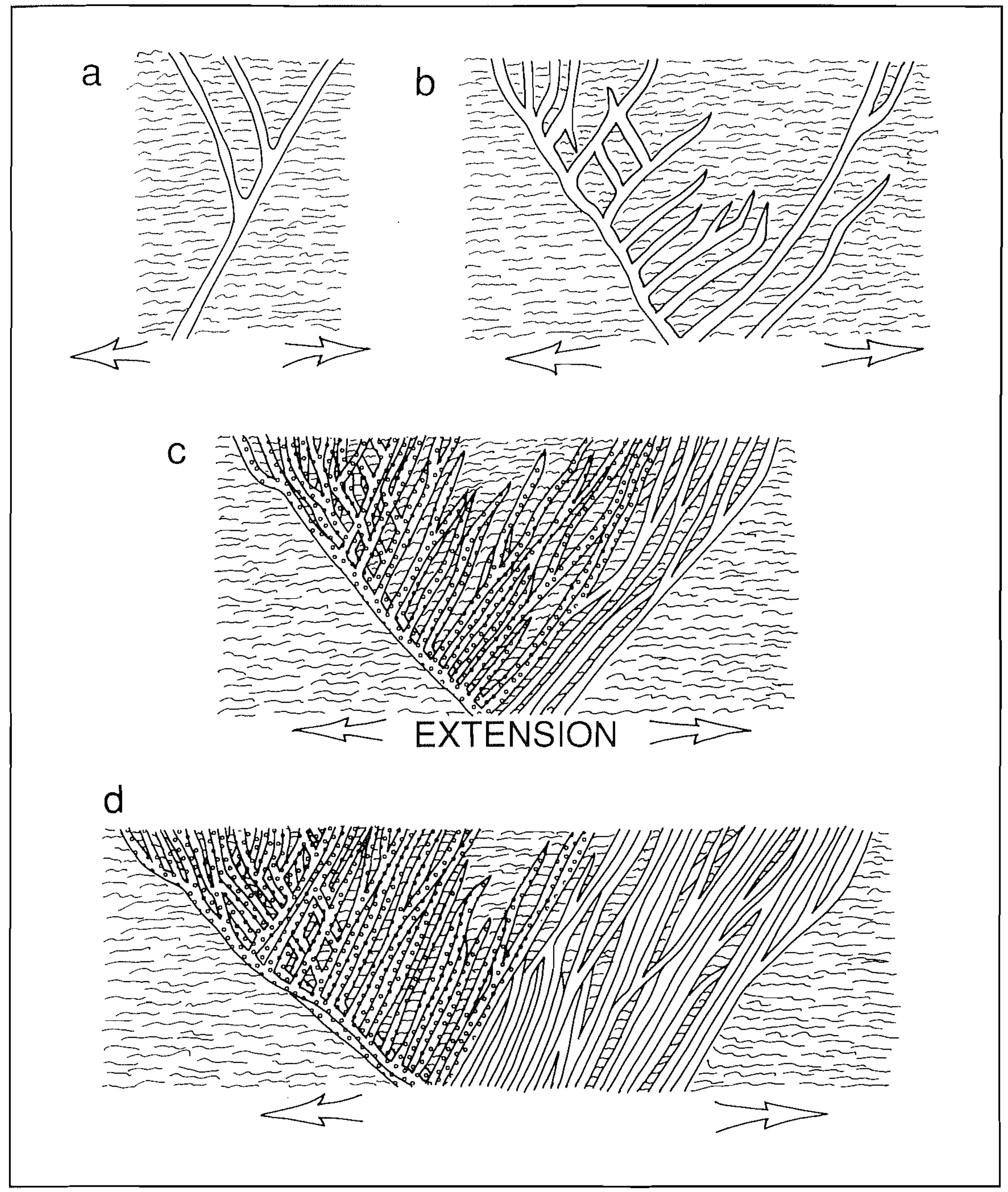

Figure 6. Idealized models of extension that produces a swarm of dikes, such that different dikes have varying attitudes from the time of intrusion. Symbols are the same as those used in Figure 5. a) Structure of the Comstock Lode, Nevada (Becker 1882); b) clay-cake experiment (Cloos 1971) to explain the pattern of faults around the Gulf of Mexico; c) and d) hypothetical result of continued spreading of the clay cake and filling of fractures as they are produced. Result is a dike swarm produced by extension and intrusion, limited assimilation, and upward transport and ejection of xenoliths. Xenoliths are most abundant in the zone where dips reverse. This zone represents the area of initial extension where the greatest number of xenoliths and screens were created. Vertical measurement of each panel is approximately 2-4 km.

Vedder & co-authors (1979). The structurally and stratigraphically(?) lower, probably older part of the sequence, which crops out at the north end of the quarry, is now largely overgrown. The structurally higher southern part of the sequence is well exposed because it is actively being quarried, but the quality of exposures is reduced by a large proportion of dikes and fractures, and by massive slippage on the quarry face. However, accessibility has improved: a road now connects the quarry floor to the fire road on the ridge top.

This new road exposes an intrusive contact between the pluton and the San Onofre Breccia of East End Quarry. Part of the contact appears to be between the San Onofre Breccia and the diapiric, older part of the pluton, because the surface is very irregular and bulbous, whereas dike surfaces wherever they are well exposed are subplanar. Subvertical and some subhorizontal dikes cross the contact between the diapir and its country rocks.

The quarry road also provides access to the top of the San Onofre Breccia. Clasts moderately high in the section include mostly greenschist, but upsection there is an increasing proportion of igneous clasts. The highest exposures (possibly downdropped in a fault block) show a mostly igneous breccia, with only a small fraction of 1% of schist fragments. This stratigraphically highest outcrop provides support of a model of coeval plutonism and tectonism, since the only apparent source of igneous clasts available was the same pluton that intrudes the lower part of the breccia, or perhaps the volcanic carapace of this pluton.

The new quarry face exposes a fossil-bearing bed — the first positive biostratigraphic control on the age of any part of the East End Quarry sequence. The fossils occur in a lenticular massive grey sandstone in the San Onofre Breccia about 30 m above the present quarry floor. Easily accessible dislodged blocks on the quarry floor contain well-preserved molds of the pelecypod *Miltha* cf. *sanctaecrucis* (Arnold), which has a provisional age range of early to middle Miocene.

Faults and Interpretation of Faulting History

The southeastern portion of Santa Catalina Island has been deformed during several phases of tectonism that have taken place since the beginning of Miocene time. These different events are displayed in a variety of ways.

The San Onofre Breccia in East End Quarry is composed of angular clasts derived from the Catalina Schist and volcanic rocks in varying proportions. Some clasts are nearly 1 m long. We infer that this coarse breccia formed at or near a fault scarp, which formed during the first phase of tectonism, and is analogous to the Violin Breccia of Crowell (1955) that formed along the San Gabriel fault zone (Crowell & Link 1982).

A second phase of tectonism allowed intrusion of the quartz dioritic sheets that bloated the pluton. Wood (1981) suggested that the sheets represent ring fractures around a caldera. Fractionation in such an environment would explain the felsic composition of the pluton. However, arcuate fractures or dikes that would be diagnostic of such a setting are not present. An alternative hypothesis is that the sheets intruded in a transtensional environment, in such a way that intrusion was localized, trends of various sheets could vary by more than 90°, and sheets could be faulted, brecciated, then crosscut by later sheets. We favor the latter interpretation because it allows the formation of a dike swarm and because it is compatible with what we know of the general tectonic history of the area.

If the variation of dike attitudes depicted in Figure 4 is the product of folding as shown in Figure 5, then this folding is the third phase of tectonism.

We infer that the fourth tectonic phase was the apparent low-angle faulting that placed the pluton over the Catalina Schist near the ridge top that trends west from the mouth of Silver Canyon. Although this apparent fault zone is generally obscured by landslides, the contact between the pluton and the underlying Catalina Schist generally follows topographic contours or dips shallowly northward as far west as the west edge of the map (Fig. 3). The amount and direction of displacement along this low-angle fault are unconstrained. Smith (1897) evidently thought that this flat-lying contact was intrusive and, hence, inferred a laccolithic pluton. However, the many vertical dikes that provide much of the pluton's mass attest to a different form of intrusion.

The fifth well-constrained phase of tectonism is represented by the fault zone that passes through Haypress Reservoir and the western wall of Silver Canyon (Fig. 3). This fault zone is nearly straight and apparently dips steeply to the northwest. It seems to have a vertical component of movement, not only because it separates a part of the pluton that mostly lacks xenoliths on the northwest from a part of the pluton that contains abundant xenoliths on the southeast, but also because it separates the Catalina Schist overlain by pluton on the northwest from pluton and overlying volcanic rocks on the southeast (Fig. 4). The fault zone is about parallel to the principal trend of the quartz diorite sheets; however, the significance of this parallelism is not clear.

Many faults of small displacement and joints, cut the pluton into blocks a few meters on a side. These fractures seem almost random in their trends, but are generally steeply dipping.

Discussion

Data presented in this paper increase the constraints on both the age of the pluton and of the San Onofre Breccia of East End Quarry. The relationship between them requires that the pluton be young enough to intrude the San Onofre Breccia but old enough to contribute clasts to the breccia. Since the likely alteration mechanisms would reset K-Ar ages downward, we regard 18.4 Ma (the younger end of the uncertainty in Forman's 1970 and Vedder *et al.*'s 1979 K-Ar dates on the pluton) as a minimum age for the pluton. Because 18.4 Ma falls within the early part of the early to middle Miocene stratigraphic range of the species of *Miltha* found in the San Onofre Breccia, we can confidently pin the age of the diapir and dikes and the San Onofre Breccia of East End Quarry as being between about 22 Ma (the beginning of the range of *Miltha sanctaecrucis*) and 18.4 Ma. This age range represents the oldest known time of deposition of any exposure of the San Onofre Breccia. The 19 Ma age of the pluton represents the end of a poorly constrained period of igneous activity in the borderland that lasted from about 25-18 Ma (Palmer 1965; D. Bukry, written comm. 1976; Crowe *et al.* 1976; Paul *et al.* 1976; Vedder & Howell 1980; Howell & Vedder 1981; Vedder 1987).

Two features of the pluton which have important tectonic implications are its contact relations and its sheeted character. Intrusion of the pluton separated the Catalina Schist from its erosional product, the San Onofre Breccia. The source for the breccia probably was a high-standing scarp along a major fault zone. Because of their similarity in age and composition, the dikes and the diapiric portion of the pluton are likely to be genetically related and intruded in an extensional setting. Tectonic models of the California continental margin (Atwater 1970; Engebretson *et al.* 1985) suggest that the pluton intruded into a progressively developing rhombochasm-like opening or sigmoidal extensional bend in the nascent system of borderland transform faults that parallels the San Andreas fault zone (Fig. 7). The model of plutonism in a transtensional environment is based upon ideas by G. Gehrels (pers. comm. 1983) and Guineberteau & co-authors (1987). If the pluton is in roughly its original orientation, the trend of dikes is what one would expect for a rhombochasm in the San Andreas system. If, however, Luyendyk & co-authors (1985) analysis of 90° of clockwise rotation is correct, our model of intrusion into a zone of transtension would require a sigmoidal extensional bend along a more westward-trending segment in the San Andreas

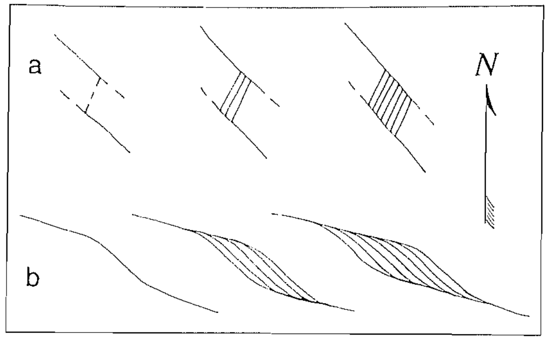

Figure 7. a) Map view of a model for the opening of a transtensional rhombochasm, which might have allowed intrusion of the swarm of sheeted dikes now exposed as the pluton on Santa Catalina Island. Northwest-trending faults are part of the San Andreas fault system. No rotation since 19 Ma. Parallel lines represent orientation of dikes. b) Model for opening of a sigmoidal releasing bend in a west-trending strand in the San Andreas fault system. After intrusion, this model would rotate 90° clockwise, as hypothesized by Luyendyk & co-authors (1985). Parallel lines represent dike orientation. Length of each drawing is 10's km.

fault system, a segment of orientation about the same as the so-called big bend area east of Los Angeles.

The foregoing observations and interpretations leave unanswered several fundamental questions: why was the opening beneath Santa Catalina Island filled from below with magma, whereas many other Cenozoic basins in southern California and the borderland, like Ridge Basin, were apparently filled more predominantly from above with sediment? Why does this setting of plutonic emplacement seem to be so rare? What was the source of magma: was it produced by adiabatic melting of crust through release of pressure? Might this intrusive event represent a last gasp of subduction-generated magma in this segment of the continental margin?

Summary and Conclusions

1. The 19 Ma pluton on Santa Catalina Island includes a high proportion (about 50%) of subvertical, dominantly northeast-trending dikes that locally reflect tectonic activity during inflation of the pluton. The mechanism of inflation is inferred to be similar to that which produces ophiolitic dike swarms, although a primitive stage of the spreading seems to be represented by the pluton.

2. The pluton may represent intrusion into a propagating rhombochasm-like opening or sigmoidal extensional bend in a transtensional fault system.

3. Although the dikes generally dip westward, they dip eastward in the western wall of Silver Canyon. This change in dip direction may be a primary feature or the product of later folding.

4. Xenoliths in the pluton generally are restricted to a northeast-trending belt between Avalon and the mouth of Silver Canyon. The belt is truncated on the northwest by a fault and dies out to the southeast either because a xenolith horizon in the pluton dips southeastward or because the xenoliths mark the site where spreading began, or some other particular site in this extensional environment. Although some xenoliths lie outside this belt, they are almost invariably of igneous composition.

5. Xenoliths in the belt are composed predominantly of lithologies of the Catalina Schist, with less vein quartz and rare San Onofre Breccia.

6. Intrusive relations, clast content, and presence of *Miltha* cf. *sanctaecrucis* (Arnold) in the San Onofre Breccia in East End Quarry constrain the breccia's age to being between about 22 and 18.4 Ma, the oldest age of any dated outcrops of the formation.

7. Southeastern Santa Catalina Island has undergone much tectonic disruption since the beginning of Miocene time. Geologic responses to tectonism include uplift, deposition of sedimentary breccia, igneous activity, localized high-angle and low-angle faulting, and widespread small-displacement faulting and jointing.

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A Review of the Seismicity of the California Islands

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Abstract - The historic seismicity of the California Islands region is represented by several significant events including the 1812 (M=7.1) earthquake which occurred near Santa Barbara, the 1812 event (M=6.9) near San Juan Capistrano, and M=5.9-6.0 earthquakes in 1862 near San Diego and 1883 near Santa Barbara. Recent activity (1900-1988) is generated by both onshore and offshore faults for M=5.0-6.0 events. Analysis of focal mechanisms by various investigators indicated both strike-slip and reverse faulting which are produced by NE-SW stresses associated with the plate motions.

Introduction

The California Islands are located in the southern California Continental Borderland which is represented by a 250 km wide offshore region with northwest-trending faults and deep sedimentary basins. Various tectonic models have been proposed for the formation of the Borderland including strike-slip faulting, folding, rifting and pull-apart basins. During late Miocene time, an episode of marine transgression and basin subsidence dominated the coastal region (Vedder & Howell 1980). Paleomagnetic evidence indicates that several of the California Islands in the Santa Barbara Channel have rotated 90° clockwise since the Miocene epoch (Luyendyk *et al.* 1985). In conjunction with the right-shear system of the San Andreas, convergent wrench tectonics is also a possible mechanism for basin development (Howell *et al.* 1980). The seismic slip rates of the faults in offshore region also contribute to the general motion between the North American and Pacific plates (Anderson 1979). Evaluation of the seismicity distribution and associated focal mechanisms reveal the current stress patterns.

Regional Seismicity

The general seismicity pattern of the California Islands is presented in Figure 1. All events with magnitude (M) greater than or equal to 4.5 are shown for 1900-1988 and larger significant events for pre-1900. The epicenter plot generally represents earthquakes with M=4.5-7.1. Selected events (M=6.0+) are listed in Table 1. Several regions of moderate activity and associated large magnitude events are evident for certain fault zones. The major event is the 1812 Santa Barbara Channel earthquake with M=7.1 (Toppozada *et al.* 1981). The estimates of the location uncertainties for the pre-1900 epicenters are 50-100 km by Toppozada *et al.* (1981). Uncertainties for events (1932-1970) are 5-15 km and 5 km after 1970 (Hileman & Hanks 1975). The spatial distribution of earthquakes shows a general correlation with certain active fault zones which is reviewed from previous investigations (Yerkes *et al.* 1981; Legg 1987).

Historical Seismicity (1800-1900): Reliable accounts regarding earthquake history of southern California start from about 1800 based on the Spanish missionary reports (Townley & Allen 1939). The historic seismicity and felt reports of the California Islands region are reviewed from the investigations by Toppozada & co-workers (1981). The following earthquake descriptions, locations and magnitudes are taken from their report.

The most significant event is the 21 December 21 1812 (M=7.1) earthquake. The missions Santa Barbara and Purisima