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VOLCANIC-RICH LITHIC SANDSTONE FROM THE EOCENE OF THE WEST-CENTRAL SAN JOAQUIN BASIN, CALIFORNIA

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ABSTRACT

Middle and late Eocene sandstone exposed in the Monocline Ridge and Ciervo Hills area and in the Orestimba Creek area of the Diablo Range at the west side of the San Joaquin Valley contains a high proportion of volcanic lithic grains. The provenance for the abundant volcanic component of these sandstone units is a problem because there is no readily apparent early Paleogene volcanic source. An early Tertiary magmatic null is indicated by the near absence of igneous rocks in the Great Basin for the interval between 65 and 40 Ma [approximately Paleocene and Eocene].

The purpose of this report is to call attention to the problem and to make available the data that I have on hand from point-counts of fifteen samples of these Eocene volcanic-rich lithic sandstones from the Monocline Ridge-Ciervo Hills area. A variety of textures is represented in the volcanic lithic grains that indicates a predominantly intermediate to silicic composition for the source volcanic rocks. Zoned plagioclase, proxenes, and hornblende are also indicative of a volcanic source. Other components in the sandstone, however, indicate at least two other sources.

The ancestral Sierra Nevada and adjacent terrane in Nevada to the east, the accretion wedge of the subduction complex to the west (now represented by the Franciscan Complex), and a hypothetical terrane outboard of the present San Andreas fault are all possible sources for the Eocene sandstone. It is concluded that the principal source for Eocene sandstone in the Diablo Range was the ancestral Sierra Nevada and that the Franciscan Complex provided a minor secondary source. The source for the abundant volcanic material in Eocene sandstone remains a problem.

INTRODUCTION

Sandstone of middle and late Eocene age exposed in the Monocline Ridge and Ciervo Hills area of the Diablo Range on the west side of the San Joaquin Valley (Fig. 1) is compositionally unusual, in that it has a high volcanic-grain component (Zimmerman, 1944; Bartow, in press). This volcanic-rich sandstone characterizes the Tumey Sandstone Lentil in the upper part of the Kreyenhagen Shale, as well as sandstone dikes in the Kreyenhagen. The abundance and freshness of the volcanic material suggests that it is first-cycle detritus. Most other Eocene sandstone in the San Joaquin Basin is characterized by a quartzo-feldspathic, or locally, by a pronounced quartzose composition.

The volcanic-rich Eocene rocks occur in the upper part of the Eocene depostional sequence that begins with the transgressive Domengine Sandstone and ends with Kreyenhagen Shale or, in the northern part of the basin, the comformably overlying regessive deposits of the Poverty Flat Sandstone (Bartow, 1991). The only other presently known area of volcanic-rich lithic sandstone in Eocene rocks is the Orestimba Creek area (Fig. 1), where sandstone dikes in the Kreyenhagen Shale and the sandstone of the lower part of the conformably overlying Poverty Flat Sandstone are compositionally similar to rocks of the Monocline Ridge area (Nilsen and Clarke, 1975; Bartow, 1985).

The Kreyenhagen Shale, based on its contained microfauna and microflora, is interpreted to have been deposited in submarine slope environment (Milam, 1985) at middle to upper bathyal or outer neritic depths (Phillips and others, 1974). The shale interval above the Tumey Sandstone Lentil contains molluscan communities that indicate two shallowing-upward cycles (Watkins, 1974). The Tumey, based on its relations to the enclosing bathyal shale, its limited areal extent, and its largely massive sandstone beds, probably represents a broad channel cut into the slope shale that was later filled by sediment gravity-flow deposits.

The provenance for the abundant volcanic component of these sandstone units is a problem, because there is no readily apparent early Paleogene volcanic source. An early Tertiary magmatic null is indicated by a "near dearth of known igneous rocks in the Great Basin between the Snake River Plain and the Arizona locus" for the interval between 65 and 40 Ma [approximately Paleocene and Eocene] (Snyder and others, 1976, p. 102). A few granitic rocks of this age are known from Nevada, but no volcanic rocks are known within a reasonable distance of the western San Joaquin Basin.

The purpose of this report is to call attention to the problem and to make available to interested parties the data that I have on hand regarding these Eocene volcanic-rich lithic sandstones. A complete analysis of the provenance for these rocks would require more sampling to accurately define the petrofacies and to delimit its extent, as well as an analysis of possible source areas. That work is beyond the scope of this report.

PALEOGENE SANDSTONE

Paleogene sandstones in the San Joaquin Basin fall into three broad compositional groups: (1) quartzo-feldspathic or arkosic sandstone, (2) quartzose and quartz-kaolinite sandstone, and (3) lithic sandstone. Quartzo-feldspathic or arkosic sandstone is predominant and is characteristic of Paleocene and lower Eocene units, as well as middle and upper Eocene marine units such as the Point of Rocks Sandstone, Tejon Formation, and Famosa Sand in the southern part of the basin (Nilsen and Clarke, 1975). Quartzose sandstone and quartz-kaolinite sandstone is characteristic of shallow-marine, deltaic, and nonmarine units in the northern part of the basin such as the Ione Formation (in the northeast), the upper part of the Poverty Flat Sandstone, the Domengine Sandstone, and, to a lessor extent, the Tesla Formation (in the northwest). Quartz-kaolinite sandstone is also common in the Eocene and Oligocene nonmarine Walker Formation in the southeastern part of the basin. The quartz-rich or quartz-kaolinite composition of these rocks appears to be related to their nonmarine and shallow-marine depositional environment.

The volcanic-rich lithic sandstone that is the subject of this report is restricted to middle and late Eocene units in the Diablo Range exposures of the western part of the San Joaquin Basin. Data available at this time do not permit a more precise definition of the limits of the petrofacies, but it does not seem to be present south of the latitude of Coalinga. The northern limit, if the quartzose sandstone of the Poverty Flat Sandstone in the Orestimba Creek area is included in the petrofacies, is the erosional truncation of the Eocene section by Oligocene nonmarine strata along the southern margin of the Stockton Arch (Bartow, 1991)

Lithic sandstone of the Kreyenhagen Shale and Tumey Sandstone Lentil

Sandstone dikes in the Kreyenhagen Shale and sandstone of the Tumey Sandstone Lentil are lithologically virtually identical. They are typically fine- to coarse-grained and yellowish gray or medium gray or light gray, and structureless. They are commonly lightly cemented with silica, but they may be locally cemented with calcite. The Tumey and Kreyenhagen sandstone superficially resembles gray, volcanic-rich, lithic sandstone of the overlying Temblor Formation in the Ciervo Hills, but the two units differ in detail (Bartow, in press).

PETROGRAPHY

Nine sandstone samples from the Tumey Sandstone Lentil and six from sandstone dikes in the Kreyenhagen Shale were point-counted according to the Gazzi-Dickinson method (Ingersoll and others, 1984). The thin sections were stained for potassium feldspar but not for plagioclase. Plagioclase is easily distinguished from other unstained minerals. Generally more than 600 points was counted per thin section in order to achieve a total framework-grain count of over 400 points. The point-count and recalculated parameters, defined in Table 1, are a minor modification of the grain parameters defined by Dickinson (1970), Graham and others (1976), and Ingersoll and Suczek (1979); the volcanic lithic-grain categories follow those of Ingersoll and Cavazza (1991). The point-count results are shown in Table 2 and the recalculated parameters are shown in Table 3. The samples cluster near the center of a triangular QFL plot (Fig. 2) and fall mostly between the fields for magmatic arc provenances and recycled orgen provenances of Dickinson and Suczek (1979) which suggests contributions from more than one source.

Mineralogy

Quartz and chert.—Most quartz is monocrystalline and may have either undulose or uniform extinction. Polycrystalline[1] quartz is present, but it is rare in most of the rocks counted. A few of the polycrystalline quartz grains have sutured crystal boundaries. Some clear, monocrystalline quartz grains with uniform extinction and rounded outlines may be volcanic quartz, but their shapes are generally irregular and they lack the characteristic ß-quartz habit. Following Dickinson (1970, p. 700), only "essentially pure quartz-chalcedony grains" are counted as chert[2] and their number seldom exceeds 10 out of 400 framework grains. Impure or dirty chert grains were counted as sedimentary lithic grains.

Feldspar.—Both plagioclase and potassium feldspar are present and, with two exceptions, plagioclase is most abundant. Much of the plagioclase is zoned and, in some of the rocks, it has been reduced to skeletal grains by alteration. The potassium feldspar includes rare microcline.

Volcanic lithic grains.—Volcanic lithic grains are the most abundant lithic grain type and average about 18% of the framework grains. They represent more than 50% of total lithic grains in the Tumey and nearly 50% in the Kreyenhagen sandstones (Fig. 3). The volcanic grains were counted in five categories, vitric, granular, seriate, microlitic, and lathwork, following Ingersoll and Cavazza (1991).

Vitric grains are rare, but they are present in most samples. Both vitrophyre and glass are represented; most are partially altered, but a very few grains of unaltered glass are present.

Granular volcanic grains include the more even textured silicic volcanic rocks within the group classified as felsitic volcanic rocks by Dickinson (1970). They occur in varying amounts that average 2-3% of the framework grains.

Seriate volcanic grains, averaging about 4% of the framework grains, include the remainder of the felsitic types that are generally porphyritic and have a wide range of grain sizes and shapes. This category includes volcanic grains that do not fit the other categories, in most cases because of

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[1] Polycrystalline, for purposes of this report, is defined as an assemblage of crystals greater than about 0.0625 mm that together make up a clastic grain. Individual crystals of polycrystalline quartz are counted as monocrystalline quartz.
[2] Chert, for purposes of this report, is defined as microcrystalline or cryptocrystalline quartz or chalcedony. This is contrary to common usage, in which chert is classified as polycrystalline quartz.

the high degree of alteration. The seriate category is, thus, somewhat of a "garbage-can group," which partly explains their relative abundance.

Microlitic volcanic grains are rare in most of the samples. This volcanic grain type grades into vitrophyric types on one hand and into lathwork types on the other.

Lathwork volcanic grains are the most abundant category and average about 9% of the framework grains in the Tumey sandstone and about 6% in the Kreyenhagen sandstone.

Sedimentary lithic grains.—The sedimentary lithic grain category includes impure chert, siltstone and claystone. These grains average 10-12% of the framework grains and, with one or two exceptions, make up 25-50% of the lithic grains. The siltstone and claystone are generally brown, argillaceous rocks with a marked preferred orientation of phyllosilicate minerals. The impure chert ranges from nearly pure cryptocrystalline chalcedony containing virtually no inclusions to dense reddish rocks with round clear inclusions and quartz veins. The round, clear inclusions probably represent altered radiolarians.

Metamorphic lithic grains.—Metamorphic lithic grains are the least common lithic grain type. They make up 2-3% of the framework grains and average less that 10% of the lithic grains. The commonest type is an aggregate of quartz and feldspar with white mica or chlorite and sometimes an amphibole. A rare type appears to be a metachert, that is, an impure chert with a schistose fabric. Many would be classified as tectonites (Dickinson, 1970), but some show no indications of a schistose fabric.

Mica.—The mica content is variable, but averages about 2-3% of the framework grains. Biotite is most common and muscovite is present in small amounts is most samples.

Accessory minerals.—The accessory mineral content is also varable and averages less than 3% of the framework grains. Common green/brown hornblende is most common. Most samples also have minor amounts of basaltic hornblende showing brown to red-brown pleochroism. Pyroxene is also present, clinopyroxene being most common. Sphene and epidote(?) are rare. Heavy minerals were separated from one sample (DR87-17) that contains, by point count, 15% assessory minerals. The separate consists of abundant pyroxene (estimated at 75-80%), including both clinopyroxene and orthopyroxene, common sphene, less common epidote(?), and very rare zircon.

Miscellaneous.—The miscellaneous category includes glauconite, chlorite, microfossil fragments, and opaque clots. A few glauconite grains are present in most samples as green or brown rounded pellets. Chlorite, present as aggregates of small flakes, is rare in a few samples. Microfossil fragments are a conspicuous but volumetrically insignificant constituent in virtually all samples. The opaque clots are unidentifiable clasts that are probably the highly altered remains of lithic grains.

Summary

The high proportion of mostly fresh-looking volcanic grain types indicates that a source area containing abundant volcanic rocks was present within a drainage basin bordering the San Joaquin Basin. The volcanic grains show variation in degree of alteration from sample to sample that can be ascribed, on the basis of other evidence of diagenetic alteration in the same sample, to post-depositional alteration. In a few samples, notably DR87-17, the volcanic grains are remarkably fresh appearing, as are the feldspars and accessory minerals. The variety of textures represented indicates a predominantly intermediate to silicic composition for the volcanic source rocks. The zoned plagioclase, the proxenes, and perhaps much of the hornblende are also indicative of a volcanic source.

The next largest group of lithic grains are the sedimentary lithic grains. Most of these, that is, the siltstone and claystone and perhaps some of the impure cherts, are probably intraclasts derived from older deposits in the basin. Most of the impure cherts are not indicative of any particular terrane, but could have come from any older sedimentary terrane. The red radiolarian cherts, however, are very probably derived from the Franciscan Complex.

The metamorphic lithic grains, as with most of the impure cherts, do not suggest any particular source. They, along with the quartz and the potassium feldspar could have been derived from any older crystalline rock terrane.

In summary, an area of volcanic rocks was a major source, but there was also a significant contribution from plutonic rocks, and a minor contribution from the Franciscan Complex. Sample DR87-17 differs from the average in that it is composed almost entirely of relatively unaltered volcanic detritus, but it provides clear evidence that a source of abundant unaltered volcanic detritus must have been present.

Sample DR87-16, on the other hand, is anomalous (Figs. 2, 3). Although a minor amount of volcanic detritus is present, sample DR87-16 bears a closer resemblance to other Eocene quartzose sandstones that were deposited in shallow marine environment. Samples DR87-16 and DR87-17 were collected from the same sandstone body, stratigraphically above the main Tumey

Sandstone Lentil, and within a few meters of each other. DR87-16 was immediately above an in-situ oyster bed, and DR87-17 below the oyster bed. Similar relations are shown by the Poverty Flat Sandstone in the Orestimba Creek area (Fig. 1) where quartzose sandstone in the upper part of the unit overlies volcanic-rich lithic sandstone in the lower part, although no oyster beds are present there.

PROVENANCE

At least three source terranes might possibly have provided sediment for the Eocene San Joaquin Basin. These are: (1) the ancestral Sierra Nevada and adjacent terrane in western Great Basin to the east, (2) the accretion wedge of the subduction complex to the west, and (3) a hypothetical terrane outboard of the present San Andreas fault that would have been laterally transported far to the northwest since the Eocene. The Eocene detritus may, of course, of been derived from more than one source.

The ancestral Sierra Nevada and adjacent Great Basin might be expected to provide mostly quartz and feldspar from Mesozoic plutonic rocks, along with detritus from older metasedimentary and metavolcanic rocks of greenschist or lower metamorphic grade. The northernmost Sierra Nevada would be included in this area because basin reconstruction indicates significant southward longitudinal transport of Paleogene sediment (Dickinson and others, 1979). There are no known late Mesozoic or early Tertiary volcanic rocks in the region today. Yeend (1974) in a study of the Paleocene(?) and Eocene age ancestral Yuba River system in the northern Sierra Nevada, concluded that the river might have been as much as 150 miles long and, thus, headed in western Nevada. There are no known early Paleogene volcanic rocks in western Nevada and no evidence of volcanic detritus in the ancestral Yuba River gravels. Andesitic and related rocks in the 43 to 34 Ma age range are found in central and eastern Nevada (Stewart and Carlson, 1976). The oldest of these might have been a source for middle and late Eocene sandstone in California, except that there is no evidence of any Paleogene drainage system extending that far east.

The accretion wedge, represented today by the Franciscan Complex, provides mostly graywacke and chert detritus along with variable amounts of quartz and minor amounts of basic volcanic rocks (greenstone) and metasedimentary rocks. The Franciscan greenstone bears little resemblance to the volcanic detritus in the Eocene sandstone. Very minor blueschist or ophiolitic detritus from tectonically included bodies of rock are sometimes present. The possibility of a hypothetical outboard, and now disappeared, terrane is remote, but must be considered. Its possible composition, of course, would be entirely speculative but would necessarily include volcanic rocks.

The quartz, feldspar, most of the metamorphic lithic grains, the green hornblende, and the micas in the Eocene sandstones could have come from the ancestral Sierra Nevada. The bulk of the Eocene detritus may well have come from the Sierra Nevada, but that source alone could not have provided the volcanic component. The early Paleogene magmatic arc was far to east or northeast and no Paleocene or early Eocene volcanic rocks are known in the Sierra Nevada.

The red radiolarian chert is most probably derived from the Franciscan Complex. This is a small component of the total sandstone, although other minor and less diagnostic constituents from the Franciscan Compex may be present. Some of the more altered volcanic lithic grains might conceivably have been derived from the Franciscan. The Franciscan was, then, at least a minor secondary source.

The hypothetical western terrane is, quite simply, an unknown. The only reason to suggest its possible presence is to provide a source for the abundant, first cycle volcanic detritus. There is no other evidence to support such a terrane, and the Eocene lithic sandstone of the Diablo Range should not, by itself, be considered to have provided such evidence.

CONCLUSIONS

On the basis of detrital sandstone composition, it is concluded that the principal source of sediment for the Eocene sandstone of the western San Joaquin Basin was the ancestral Sierra Nevada and that the Franciscan Complex provided a minor secondary source. The source for the abundant volcanic material in volcanic-rich lithic sandstone in the Diablo Range remains unknown. The early Paleogene magmatic arc was far to the northeast and east and beyond the reach of any known Paleogene river systems. Even if early Paleogene volcanic rocks were present in the western Great Basin, there would be a problem in transporting the abundant volcanic detritus through the area of the western Sierra Nevada where Paleogene sedimentary rocks correlative with the middle and late Eocene sandstone of the Diablo Range contain little or no volcanic detritus. The appeal of a mysterious western terrane that has now vanished has its limitations and its hypothesized presence cannot, on the basis of present evidence, be taken seriously.

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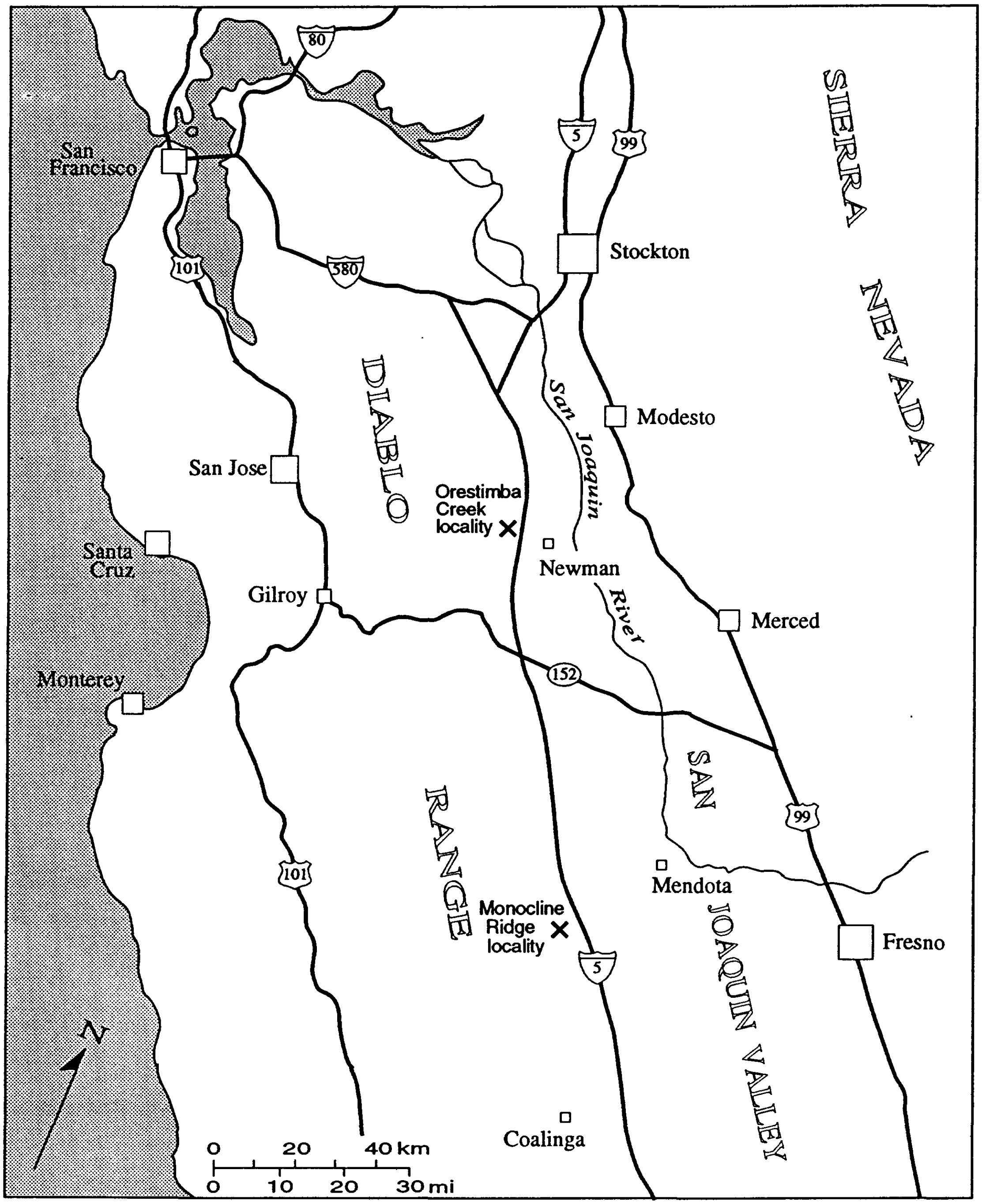

Figure 1.--Index map of central California showing localities where Eocene volcanic-rich lithic sandstone has been found.

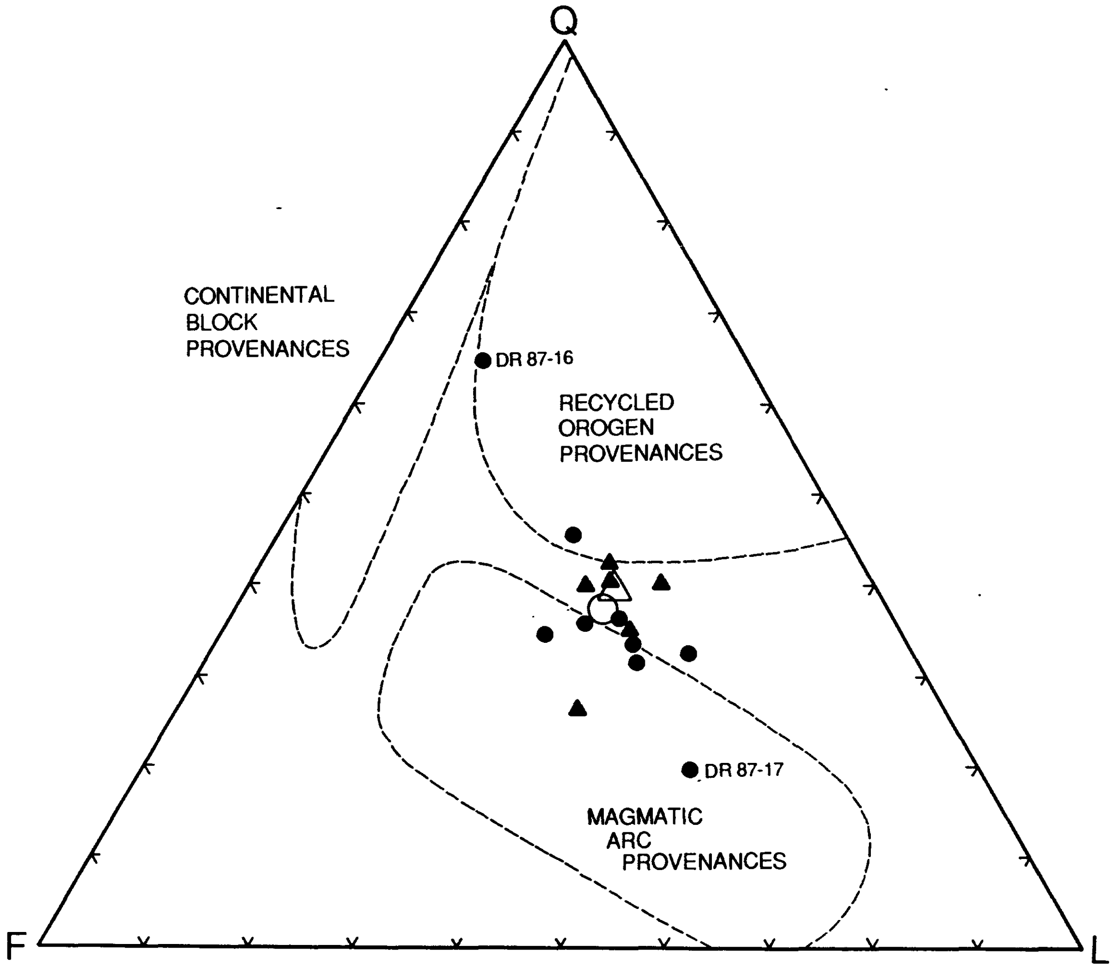

Figure 2.--Triangular QFL (quartz-feldspar-lithic grain) plot of sandstone samples from Eocene units of the west-central San Joaquin Basin. Solid circles--Tumey Sandstone Lentil of the Kreyenhagen Shale, solid triangles--sandstone dikes in the Kreyenhagen Shale. Larger open circle and triangle are averages for the Tumey and Kreyenhagen, respectively. Dashed lines represent the fields for principle provenance types as defined by Dickinson and Suczek (1979).

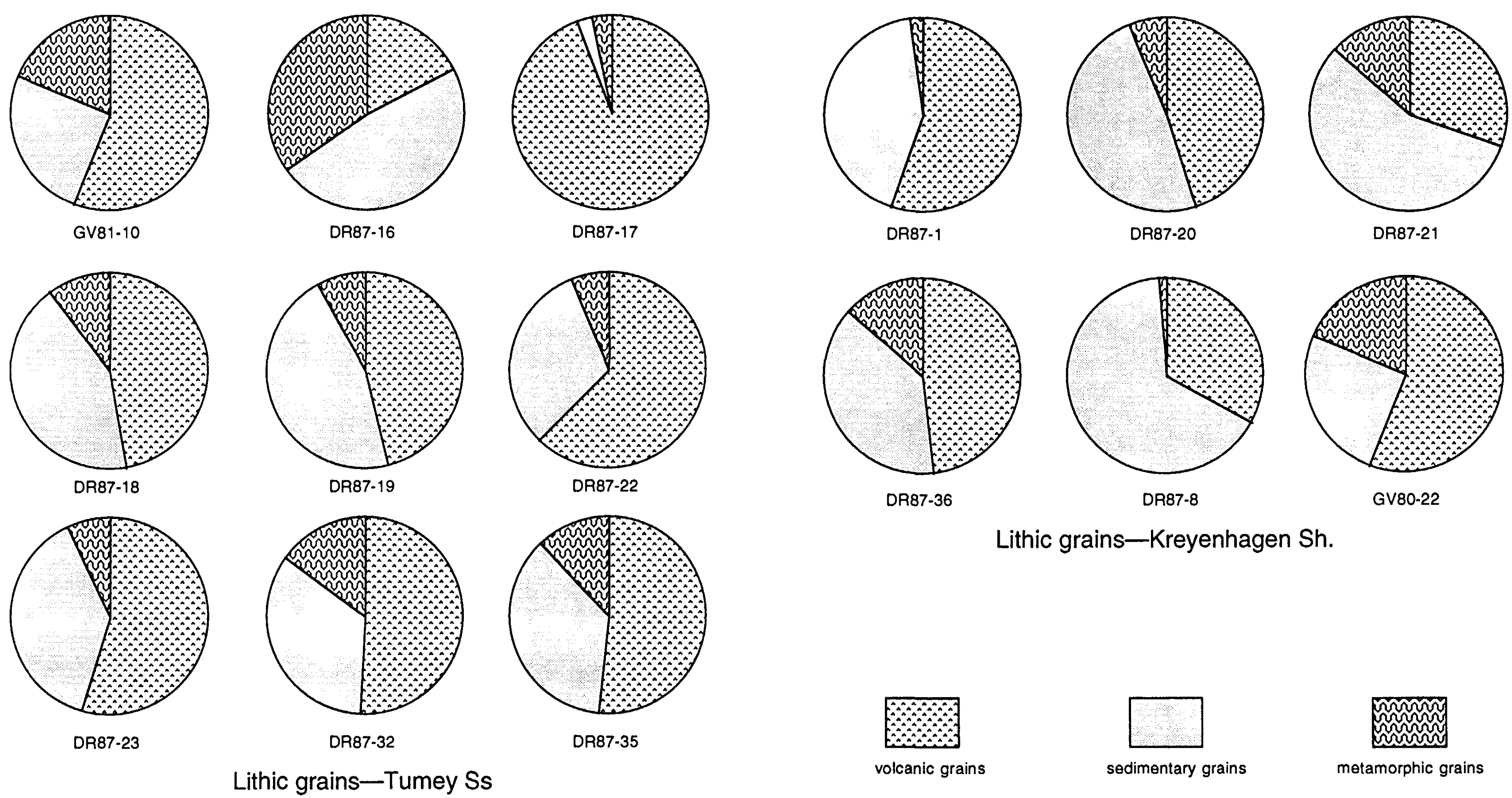

Figure 3.--Pie diagrams showing the relative proportion of volcanic, sedimentary, and metamorphic lithic grains in sandstone samples from the Tumey Sandstone and Kreyenhagen Shale.

Table 1.—*Point-counted and recalculated mode parameters*

	Point-counted categories
Qm	Monocrystalline quartz
Qc	Chert (micro- or cryptocrystalline quartz)
P	Plagioclase
K	Potassium feldspar
Lvv	Vitric volcanic lithic grain
Lvg	Granular volcanic lithic grain
Lvs	Seriate volcanic lithic grain
Lvm	Microlitic volcanic lithic grain
Lvl	Lathwork volcanic lithic grain
Ls	Sedimentary lithic grain
Lm	Metamorphic lithic grain
M	Mica
Ac	Accessory grain
Misc	Unidentified and minor constituents
	Recalculated categories
Q	Qm + Qc
F	P + K
Lv	Lvv + Lvg + Lvs + Lvm + Lvl
L	*Lv* + Ls + Lm
Lt	*L* + Qc (Total lithic grains)
QFL %Q	100 *Q*/(*Q*+*F*+*L*)
QFL %F	100 *F*/(*Q*+*F*+*L*)
QFL %L	100 *L*/(*Q*+*F*+*L*)

Table 2.—*Point-count results for selected Eocene lithic sandstones from the Diablo Range*

SAMPLE	n*	Qm	Qc	*Q*	P	K	*F*	Lvv	Lvg	Lvs	Lvm	Lvl	*Lv*	Ls	Lm	*L*	*Lt*	M	Ac	Misc
Tumey Ss																				
GV61-10	446	131	4	*135*	72	40	*112*	2	12	17	4	37	*72*	33	24	*129*	*133*	11	23	36
DR87-16	417	265	1	*266*	27	77	*104*	0	2	3	0	2	*7*	19	14	*40*	*41*	3	0	4
DR87-17	454	72	2	*74*	85	19	*104*	4	21	35	26	98	*184*	5	6	*195*	*197*	0	68	12
DR87-18	416	169	4	*173*	62	37	*99*	1	4	14	9	23	*51*	46	11	*108*	*112*	5	9	22
DR87-19	436	136	6	*142*	86	54	*140*	1	8	10	8	31	*56*	58	10	*126*	*132*	18	0	12
DR87-22	421	121	6	*127*	55	36	*91*	9	14	13	6	39	*61*	41	8	*130*	*136*	18	19	38
DR87-23	424	116	9	*125*	53	30	*83*	1	27	21	2	45	*96*	66	12	*176*	*185*	9	9	22
DR87-32	425	121	13	*134*	83	41	*104*	0	13	21	9	38	*81*	55	24	*160*	*173*	13	7	7
DR87-35	415	110	11	*121*	81	23	*104*	3	10	30	2	37	*62*	58	19	*159*	*170*	12	7	12
Average		*136*	*6*	*144*	*65*	*40*	*105*	*2*	*12*	*16*	*7*	*39*	*79*	*43*	*14*	*136*	*142*	*9*	*16*	*18*
Kreyenhagen Sh																				
GV80-22	422	95	2	*97*	96	34	*130*	6	11	18	33	51	*119*	14	9	*142*	*144*	19	14	19
DR87-1	425	141	3	*144*	64	42	*106*	3	17	30	5	33	*86*	89	3	*160*	*163*	5	3	7
DR87-20	416	162	3	*165*	57	37	*94*	1	9	19	0	30	*59*	84	8	*131*	*134*	5	1	20
DR87-21	410	147	3	*150*	69	24	*93*	2	8	17	1	13	*39*	72	17	*128*	*131*	18	3	18
DR87-36	423	152	11	*163*	65	48	*113*	7	3	22	3	26	*63*	50	18	*131*	*142*	11	0	5
DR87-8	300	86	3	*69*	19	26	*45*	0	17	9	1	2	*29*	58	1	*86*	*91*	38	0	42
Average		*130*	*4*	*135*	*62*	*35*	*97*	*3*	*10*	*19*	*7*	*26*	*66*	*54*	*9*	*130*	*134*	*16*	*4*	*18*

*framework grains

Table 3.—*Recalculated grain parameters for selected Eocene lithic sandstones from the Diablo Range*

SAMPLE	n*	QFL %Q	QFL %F	QFL %L	P/F	Lv/L	Ls/L	Lm/L
Tumey Ss								
GV81-10	446	35.9%	29.8%	34.3%	0.643	0.558	0.256	0.186
DR87-16	417	64.9%	25.4%	9.8%	0.260	0.175	0.475	0.350
DR87-17	454	19.8%	27.9%	52.3%	0.817	0.944	0.026	0.031
DR87-18	416	45.5%	26.1%	28.4%	0.626	0.472	0.426	0.102
DR87-19	436	34.8%	34.3%	30.9%	0.614	0.460	0.460	0.079
DR87-22	421	36.5%	26.1%	37.4%	0.604	0.623	0.315	0.062
DR87-23	424	32.6%	21.6%	45.8%	0.639	0.545	0.386	0.068
DR87-32	425	33.7%	26.1%	40.2%	0.606	0.506	0.344	0.150
DR87-35	415	31.5%	27.1%	41.4%	0.779	0.516	0.365	0.119
Average		37.5%	27.2%	35.3%	0.621	0.582	0.313	0.105
Kreyenhagen Sh								
GV80-22	422	26.3%	35.2%	38.5%	0.738	0.838	0.099	0.063
DR87-1	425	35.1%	25.9%	39.0%	0.604	0.550	0.431	0.019
DR87-20	416	42.3%	24.1%	33.6%	0.606	0.450	0.489	0.061
DR87-21	410	40.4%	25.1%	34.5%	0.742	0.305	0.562	0.133
DR87-36	423	40.0%	27.8%	32.2%	0.575	0.481	0.382	0.137
DR87-8	300	40.1%	20.3%	39.6%	0.422	0.330	0.659	0.011
Average		39.5%	25.1%	35.4%	0.608	0.436	0.419	0.072

*framework grains