Keeler Dunes

Mineralogical Analyses to determine sand source(s)

Revised report

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The source of sand for the Keeler Dunes was investigated by comparing the mineralogy of the Keeler Dunes with that of sand from potential sources. These include washes draining from the Inyo Mountains to the east of the Keeler dunes; and fluvial sands of the Owens River delta, with associated sand sheets covering the northeast sector of Owens Lake.

Surface sand samples were collected from all parts of the Keeler Dunes, together with representative parts of the Swansea Dunes. Sand was also collected from fluvial (river deposited) sand adjacent to the Owens River channel and the delta and from two washes on the Keeler fan above the area affected by sand sheets and sands blown up the fan from the Keeler Dunes. Sample locations are given in Table 1 and Figure 1.

Samples were analyzed for particle size using sieving and bulk mineralogy using XRD (X-ray Diffraction) at the DRI Soils Laboratory. Details of the methods are given in Appendix 1.

Table 1: Sample Locations

Sample	Northing	Easting	Description
OL-11-001	4046226	411516	sand from old channel of Owens River
OL-11-002	4044698	412549	adjacent to Owens River delta channel
OL-11-003	4044736	415742	NW end of Swansea Dunes
OL-11-004	4039172	420654	Southern dunes, crest
OL-11-005	4040245	419447	west end of linear dune
OL-11-006	4040340	419375	cross bedded sand
OL-11-007	4040669	419271	west end of Horseshoe dune
OL-11-008	4041079	419038	north sand sheet
OL-11-009	4041803	419030	Swansea dunes
KF wash 1	4041613	420975	Keeler Fan
KF wash 2	4041553	421101	Keeler Fan

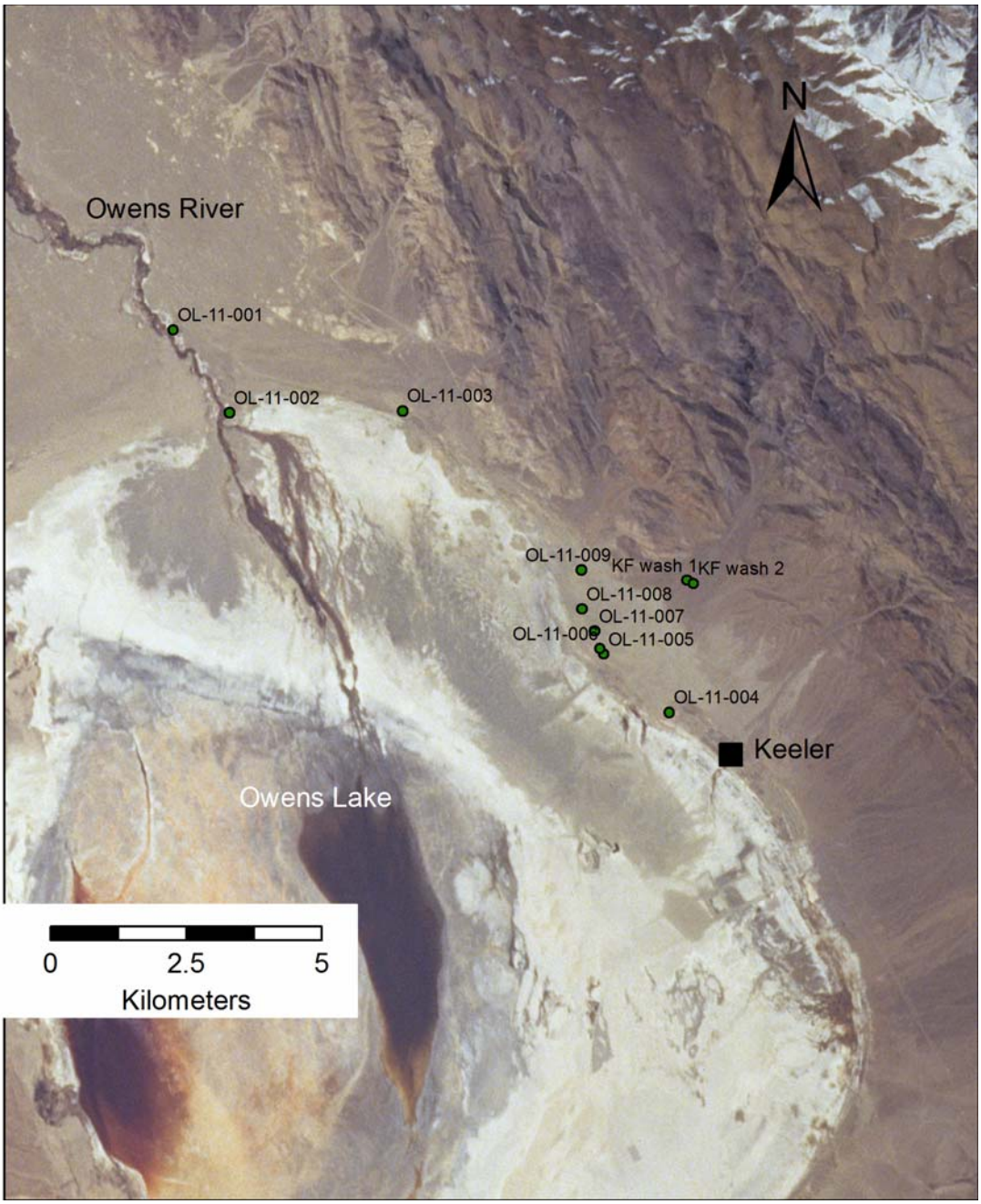

Fig. 1. Location of samples collected for bulk XRD analysis of mineralogy

Results

Bulk Mineralogy

The XRD scans fall into two main groups: (1) samples from the Keeler Fan washes; and (2) sands from the Keeler and Swansea Dunes and the Owens River delta. All nine samples from Group 2 were very similar in mineral composition but significantly different from those in Group 1 (see Table 2).

The sands from Group 1 were similar to each other. Results indicate that quartz is the dominant mineral (>50%), and calcite is the only other major mineral (>20%) present. Plagioclase (probably albite) and mica (probably muscovite) are present in minor amounts (<10%), and K-feldspar and hematite may be present in trace amounts (<5%).

For Group 2 (Keeler-Swansea dunes, Owens River delta), the following minerals were identified: Quartz (major), Plagioclase (major), K-feldspar (minor), Calcite (minor to trace), and Amphibole (trace). Table 2 shows the results of the semi-quantitative analysis. Quartz content varies between 30 and 41%; with Plagioclase between 38 and 43%; and K-feldspar ranging from 12 to 16%. The compositional data are plotted as ternary diagrams in Figures 2 and 3.

Table 2. Results of semi-quantitative bulk XRD analysis

Field ID	Lab ID	Semi-quantitative XRD results					
		Quartz - % -	**Plagioclase** - % -	**K-feldspar** - % -	**Calcite** - % -	**Other** - % -	**Total** - % -
OL-11-001-Owens River Old Channel	18-839	40	43	15	1	1(1)	100.0
OL-11-002 Delta Well	18-840	38	42	16	3	1	100.0
OL-11-003 NW Swansea dunes	18-841	37	40	15	6	2	100.0
OL-11-004 Southern Dune	18-842	39	38	10	11	2	100.0
OL-11-005 West End linear Dune	18-843	38	40	14	7	1	100.0
OL-11-006 Cross-bedded Sand	18-844	35	43	13	8	1	100.0
OL-11-007 North Dune and Sand Sheet	18-845	41	39	12	7	1	100.0
OL-11-008 Horseshoe Dune	18-846	39	39	14	7	1	100.0
OL-11-009 South end of Swansea Dunes	18-847	38	40	15	6	1	100.0
KF-wash 1	13-046	57	8	3	25	7(1)	100.0
KF-wash 2	13-047	54	6.5	3	30	6.5(1)	100.0

(1) Other for OL samples is amphibole
(2) Other for Keeler fan samples includes 6% mica (muscovite) and 1% hematite

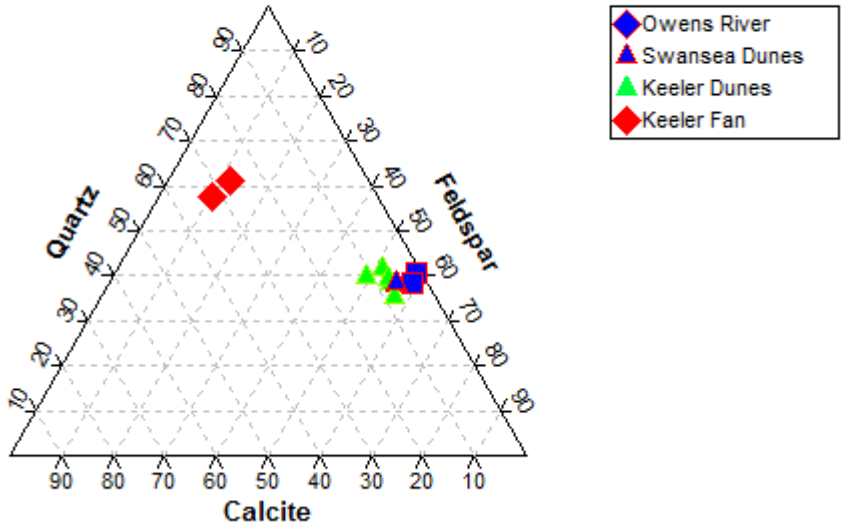

Fig.2: Ternary diagram showing proportions of quartz, calcite, and feldspar in collected samples.

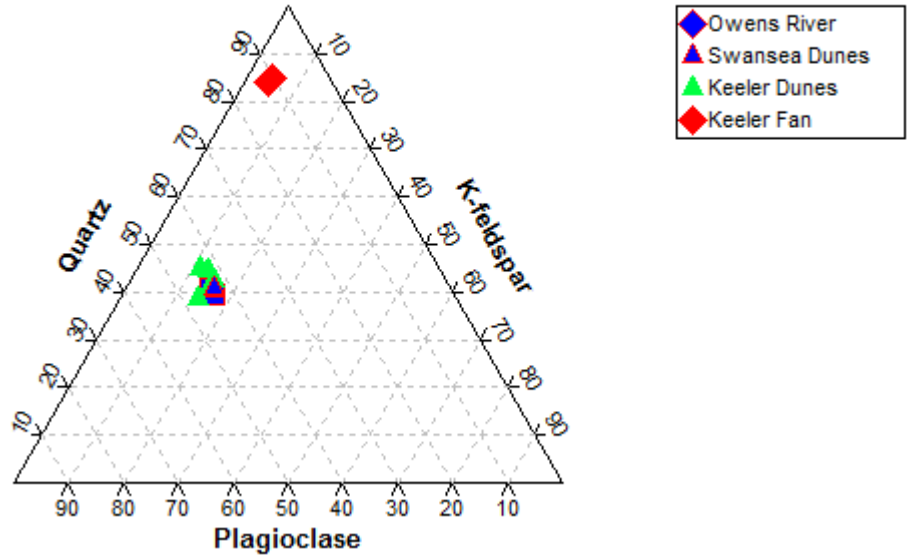

Fig. 3: Ternary diagram showing proportions of quartz, K-feldspar and Plagioclase in collected samples.

Discussion

The sand from the Keeler and Swansea dunes is much coarser and more poorly sorted than is typical for aeolian sands. Even the cross-bedded sand unit is only moderately sorted, similar to the sand that comprises the southern dunes. This suggests that the sand has not been transported very far from its source. There is a general, but not pronounced, decrease in mean grain size and improvement in sorting from NW to SE, parallel to the dominant sand transport direction.

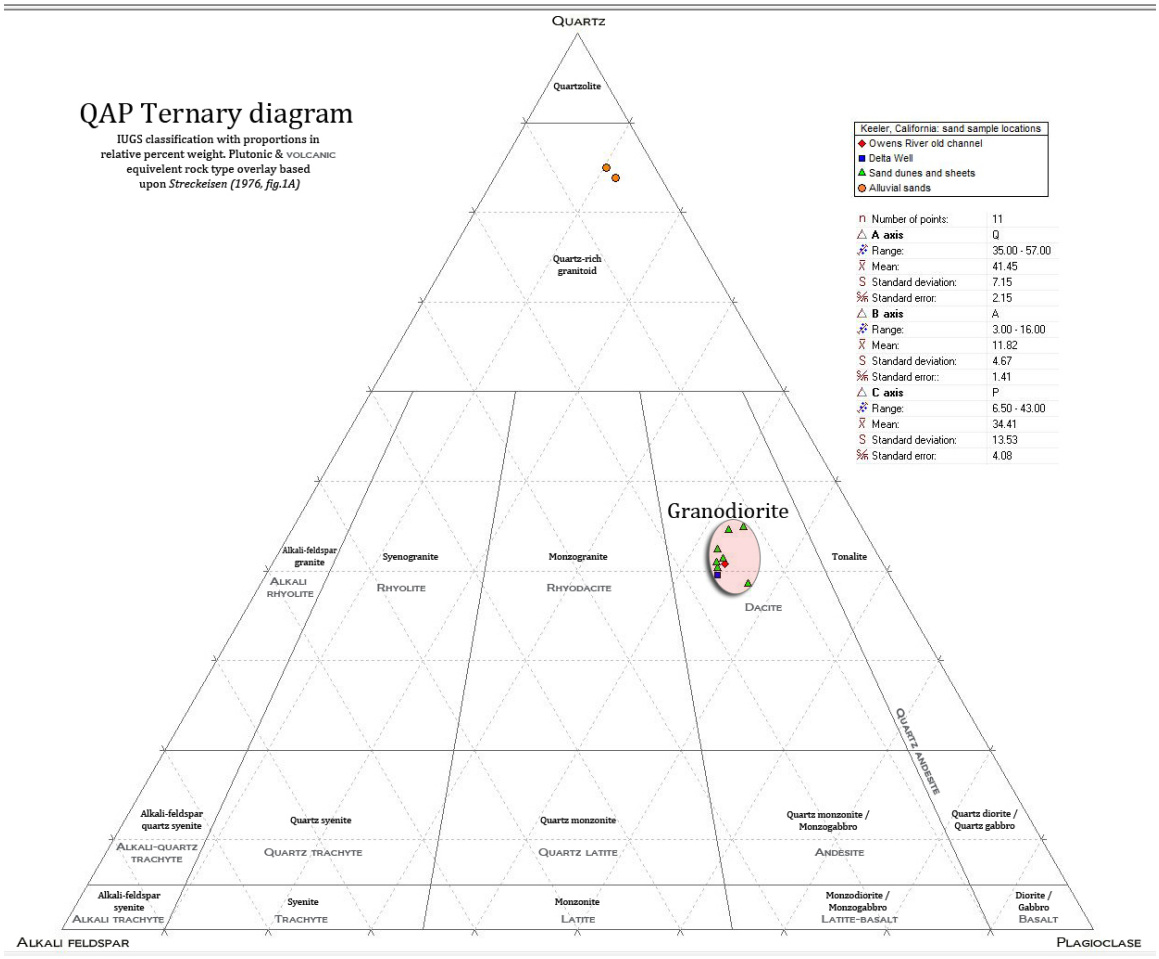

Fig. 4: Ternary diagram to show relationship between collected samples and composition of source rocks.

The relative proportions of quartz, K-feldspar and plagioclase in the sands from the Owens River, as well as the Keeler and Swansea dunes indicates that they are derived from a granodiorite source rock – as found in the Sierra Nevada (Fig. 4). The sand contains a high percentage of plagioclase and K-feldspar (> 50%), indicating that it is has not been exposed to significant chemical weathering and is mineralogically very immature. This indicates a short transport path and residence time in the fluvial and aeolian environments (in other words, this is young sand that

has not been transported very far). The composition of these sands is very similar to those found in the Mojave Desert (Table 1 in (Scheidt et al., 2011)).

There is no discernible difference between the Swansea Dunes and the Keeler Dunes, based on this analysis. Likewise, there is no difference mineralogically between the sand that comprises all parts of the Keeler Dunes today and older sands (e.g. the cross bedded sand) that have been dated in this case to 1710 yr B.P.

By contrast, the sand from the Keeler Fan washes is quite different with dominant calcite derived from Early Permian and Pennsylvanian-age marine sedimentary rocks (e.g. Lone Pine Formation; Keeler Canyon Formation) in the Inyo Mountains; the quartz. The sands are characterized by a very low feldspar content, suggesting that they have been derived from pre-weathered and transported sediments. Stone et al. (2004) report detrital quartz sandstone units in both the above formations, suggesting a source for the quartz in the Keeler Fan wash sediments. Other possible sources of quartz include the Miocene Fanglomerate of Slate Canyon and Jurassic felsite intrusions, as indicated by the ternary plot (Fig 3).

Conclusions

The great similarity in bulk mineralogy between the samples from the Keeler and Swansea dunes, as well as the Owens River area strongly indicates that the majority of sand in the Keeler Dunefield is derived from the Owens River, with a very minor addition of material from the Inyo Mountains

References cited

Scheidt, S., Lancaster, N., Ramsey, M.S., 2011. Eolian dynamics and sediment mixing in the Gran Desierto, Mexico determined from thermal infrared spectroscopy and remote sensing data. Geological Society of America Bulletin, 123(7-8), 1628-1644.

Stone, P., Dunen, G.C., Conrad, J.E., Swanson, B.J., Stevens, C.H., and Valin, Z.C, 2004. Geologic Map of the Cerro Gordo Peak 7.5' Quadrangle, Inyo County, California. Pamphlet to accompany Scientific Investigations Map 2851. US Geological Survey, Reston, VA. http://pubs.usgs.gov/sim/2004/2851/

Appendix 1: Keeler Dunes – Bulk XRD Analysis

Sophie Baker

Sample Preparation:

Bulk samples were prepared by splitting out ~4g of the oven dried <2mm fraction of the sample and grinding it initially by hand in a pestle and mortar until it passes through a sieve with openings of 500µm. Samples were then ground to a powder in a McCrone mill for 8 minutes in 10 ml of methanol. Subsequently, samples were air dried overnight, gently re-crushed in a pestle and mortar to break up aggregates formed during drying, and side-loaded into specially-designed side-loading sample holders. This process of grinding the samples to a fine homogenous powder, followed by side-loading, helps to minimize preferred orientation of certain crystal phases within the samples, thereby increasing the accuracy of the semi-quantitative analysis.

Analysis parameters:

All samples were run on DRI's Bruker D8 Advance XRD equipped with a Sol-X (solid state) detector with the following scan parameters:

- 5 to 65 ° two theta scan range
- Locked Coupled Step Scan
- 0.05 ° increments (step size)
- 2 seconds/step (step time)
- Variable width divergence and anti-scatter slits (V12)

Data analysis:

The resulting XRD scans were viewed and interpreted using the Bruker XRD data evaluation software called EVA. A background correction was performed on each scan before interpretation. Minerals were identified by matching reference mineral patterns stored in the ICDD (International Centre for Diffraction Data) database to the observed peaks.

The method used to estimate the relative percentages of each mineral identified (i.e., the semi-quantitative analysis) is based on the method of Chung (1975), which assumes that all the minerals are identified correctly and that there are no unidentified phases in the sample. It is carried out within EVA by adjusting the y-scale of the reference patterns (visually represented by sticks in the plots) to match the peak heights on the observed scan. A reference intensity ratio for each mineral

(in this case, I/Ic, which is the relative height of the strongest peak of a mineral compared to the relative height of the strongest peak of corundum in a 1:1 mixture) is then used to determine the relative percentages. The calculation is done automatically by the software once each mineral selected is assigned an I/Ic value. The I/Ic values for most of the mineral reference patterns used were provided by the ICDD database. Otherwise values were taken from Davis et al. (1989). Because generic I/Ic values were used (the same basic mineral type can have a range of I/Ic values), the relative percentages of the mineral determined can be assumed only to be semi-quantitative estimations rather than quantitative values (no estimation of uncertainty can be provided). However, even though the accuracy of the percentages cannot be tested, since the same minerals were identified in all samples in the batch and the same reference patterns and I/Ic values were used throughout, the percentages are useful for comparing samples within the batch.

References:

Chung, F. H., 1975. Quantitative interpretation of X-ray diffraction patterns of mixtures. III. Simultaneous determination of a set of reference intensities. Journal of Applied Crystallography 8 (17-19).

Davis, B. L., Smith, D.K., Holomany, M.A., 1989. Tables of Experimental Reference Intensity Ratios Table No. 2, December 1989. Powder Diffraction 4:4 (201-205).