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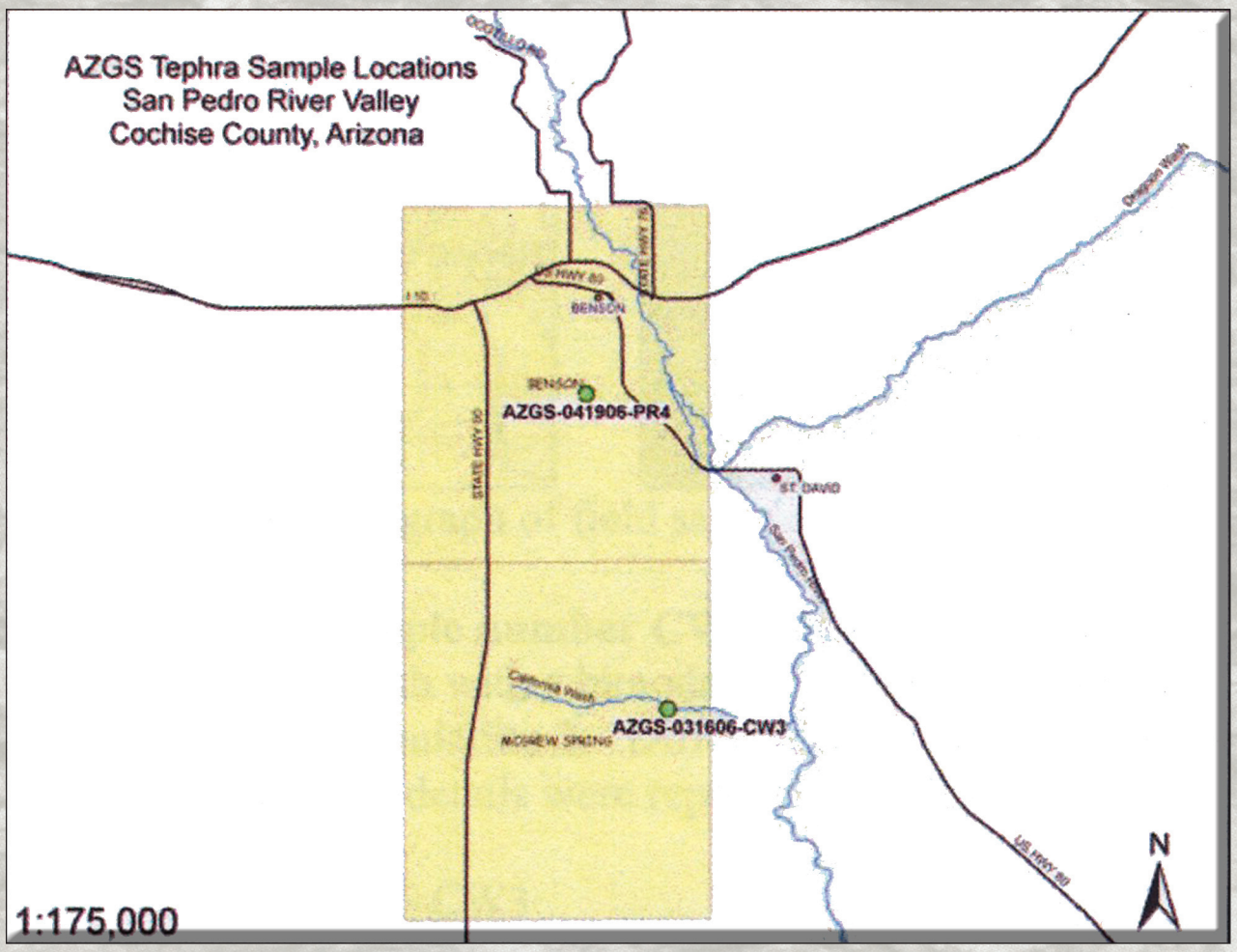


# Geochemical Fingerprint of a Plio-Pleistocene Tephra in California Wash in the Benson Area, San Pedro River Valley, Southeastern Arizona

version 1.0
June, 2007

Ann Youberg and Jon E. Spencer
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## INTRODUCTION

Much of the Plio-Pleistocene sediment in the San Pedro River Valley near Benson (Cochise County, southeastern Arizona) reflects a past depositional environment in which clastic debris was shed from valley-flanking mountains into the basin. The basin interior was characterized by a playa environment that is represented by fine sand, silt, and gypsum, whereas flanking, basin margin areas received conglomerate and sandstone derived from nearby bedrock (Smith, 1994; Youberg et al., 2003; Shipman and Ferguson, 2003). During deposition of these valley-filling sediments, several ash beds were deposited from distant volcanic eruptions. The age of this sedimentary sequence is only approximately known based on vertebrate fossils, magnetostratigraphy, and K-Ar dates on glass from the tephras. Theses studies proposed a Pliocene to Pleistocene age. Similar sediments in the lower San Pedro River Valley, which contain a tephra dated at 6 Ma, include extensive lacustrine (lake) deposits (Dickinson, 2003). The similarity between upper and lower San Pedro Valley filling sediments suggests that they are related and are of similar age, whereas available geochronologic data indicate that the lower San Pedro sediments are significantly older.

### *Previous Studies*

During the early to mid-1960s Gray (1965, 1967) conducted a sedimentologic investigation of the basin-fill deposits in the central part of the upper San Pedro River Valley. Gray formally proposed the name St. David Formation and informally divided the basin fill sediments into lower, middle and upper units. He described the sedimentology of the St. David Formation and placed rough age constraints on the deposits based on vertebrate fossil assemblages found within some of the sediments (Gray, 1965).

Haynes (1968) provided a synopsis of late Quaternary geology in the San Pedro River Valley, which was developed mainly from studies conducted at archeological sites. These studies identified periods of extensive erosion between 30,000 and 8,000 years before present, and identified sites with lacustrine, mudstone, marls and fossils, which provide a chronological record of basin erosion and deposition cycles (Haynes, 1968).

A pioneering study in 1975 applied paleomagnetic dating techniques to the terrestrial sediments of the St. David Formation (Johnson et al., 1975). Eleven complete magnetic transitions were found in the St. David Formation. Paleomagnetic reversals were correlated to the dated volcanic ashes found in California Wash (Scarburough, 1975) and below a faunal horizon at Post Ranch. These data were then used to define four datum planes for fossils of the San Pedro Valley (Johnson et al., 1975). The authors noted some problems with this methodology, including limited sampling density in coarse sediments, apparent episodic deposition resulting in incomplete sediment records, and missed paleomagnetic events (Johnson et al., 1975). More recent studies have collected new data and reinterpreted older data to update age constraints of the St. David Formation (Lindsay et al., 1990a; 1990b; Smith, 1994), and to understand depositional environments (Smith, 1994).

### *Current Geologic Mapping*

The Arizona Geological Survey (AZGS) began mapping the upper San Pedro River corridor in January, 2003, as part of the STATEMAP component of the National Cooperative Geologic Mapping Program. During the first year of mapping, three 7½' quadrangles were mapped; Benson (Youberg and others, 2003), McGrew Springs (Shipman and Ferguson, 2003), and Huachuca City (Pearthree, 2003). St. David (Youberg, 2006), Land (Shipman and Ferguson, 2005), Fairbank (Ferguson and others, 2005), and Lewis Springs (Pearthree and others, 2005) quadrangles were mapped during the winter of 2004/2005. Mapping of the upper San Pedro River corridor was completed with mapping of the Galleta Flat East quadrangle (Youberg and others, 2006), and the Hereford and Stark quadrangles (Cook and others, 2007). The lower San Pedro River Valley is currently being mapped and mapping will continue through 2009.

## TEPHRA ANALYSIS

In 2006, ten samples of tephras (fine volcanic ash derived from distant sources) from the Benson area (Figure 1) were collected in order to better constrain the age of the host sediments (Table 1). Several samples were collected from California Wash and Post Ranch to assess previously dated tephras. One of the sampled tephras had yielded a K-Ar date of 2.5 ± 0.4 Ma (Scarborough, 1975) and was placed in the lower part of the Matuyama magnetic polarity zone (younger than 2.43 Ma according to Johnson et al., 1975). This tephra was correlated with the Huckleberry Ridge tephra derived from the Yellowstone area (Izett, 1981; Izett and Wilcox, 1982), but this correlation was suggestive and not supported with geochemical or other data.

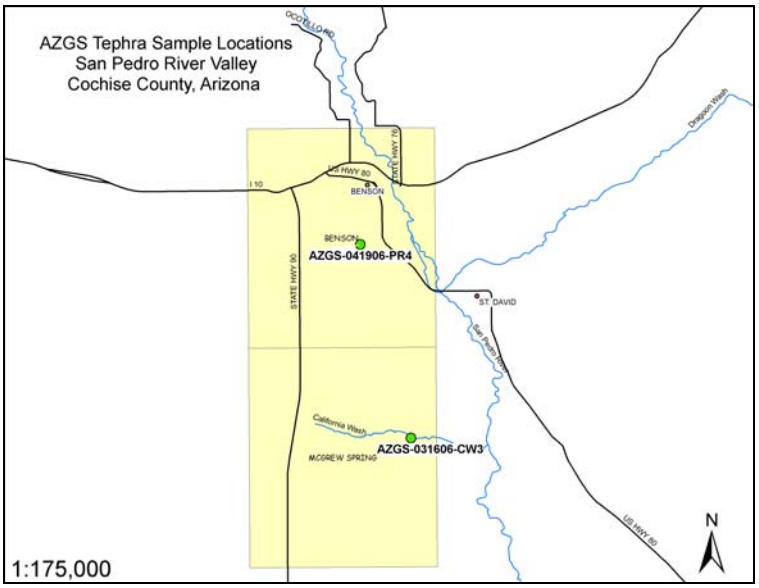


Figure 1. Locations of collected tephras submitted for analysis.

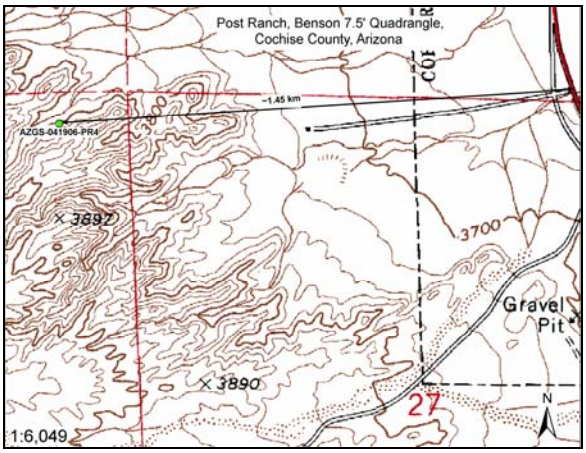
Thin-section (microscope) examination of the ten samples revealed only four that had sufficiently large and unaltered glass fragments to warrant chemical analysis, and these four were thought to represent only two tephra beds. A sample of each was sent to Elmira Wan at the U.S. Geological Survey tephrachronology laboratory in Menlo Park. Laboratory results are as follows:

**Sample AZGS-041906-PR4 (field-sample number PR-4-19-06-4, Figures 2 and 3):** After wet-sieving and acid-treatment, the sized residue contained ~100% mineral grains and microfossil fragments. Only one isotropic, probably reworked glass shard was noted on the entire oil mount. As the total abundance of

glass shards was <1%, further work on this sample was discontinued. Laboratory details were reported as follows:

Lab sample name: AZGS-041906-PR4:
Color: Light yellowish gray (5Y 9/1)
Disaggregation: Mortar and pestle/water spray
Wet-sieve: [+100], [-100=200], [-200+325]
HCl 60 HF 10 Frantz: N/A Heavy liquids; N/A

EW [-100+200] Nearly all of the grains are very heavily coated with carbonate or are ostracod, calcareous algae (charophyte)? or mollusc? fragments. Approximately 1% of the grains are subhedral feldspars. No glass shards were observed. Sieved residue was treated with acid to see if any isotropic shards are hidden beneath coatings. This removed all of the carbonate. However, only one glass shard was present on entire oil mount. Almost all of the treated ash fraction consists of highly weathered, subhedral to anhedral mineral grains (opaque minerals, plagioclase, quartz, biotite, microcline, garnet, etc.) or altered grains. Processing stopped at this point.



Figures 2 and 3. Location map and photograph of field sample number PR-4-19-06-4.

**Sample AZGS-031606-CW3 (field-sample number CW-3-16-06-3, Figures 4 and 5):** This sample consists of moderately altered volcanic ash with a bimodal composition (Table 2). The two modes are referred to below as population 1 and population 2. Differences between the modes are apparent on a Ca vs. Fe scatter-plot (Figure 6). Laboratory details were reported as follows:

Lab sample name: AZGS-031606-CW3:
Color: Light yellowish gray (10YR 5/3)
Disaggregation: Mortar and pestle/water spray
Wet-sieve: [+100], [-100=200], [-200+325]
HCl 60 HF 10
Frantz: 0.6A+8º
Heavy liquids; N/A

EW [-100+200] >99% heavily coated (FeO and clays), delicate, angular to subangular, colorless to dark brown, platy and ribbed, solid to poorly vesiculated glass shards are present in this spl. Vesicles are poorly to well-hydrated, and typically equant to irregular bubble types. Spindle and cone-shaped vesicles were observed also but these are less common. Remainder of residue is composed of compound shards, heavy and or opaque minerals (ilmenite, opx, apatite), and

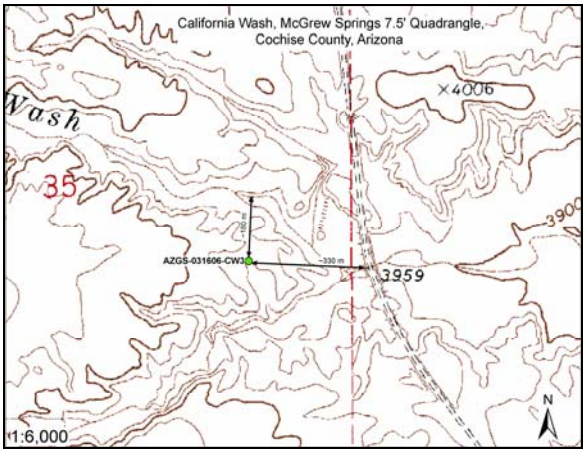
feldspars. Refractive index of shards is nearly the same as oil (R.I. 1.515). This characteristic, and the heavy coatings make it difficult to characterize shard morphology. To improve petrographic description, remove surface residues. >> ACIDS
1st

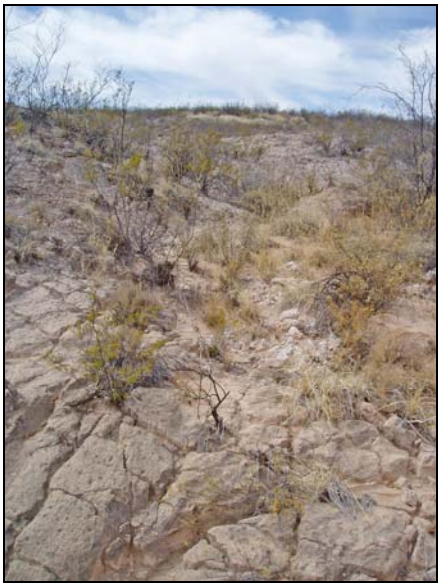
ACIDS: Shards cleaned up very nicely. Small sub-populations of glass bubbles, bubble wall, bubble-wall junction, and frothy webby shards are now noted. Still some coated altered/devitrified grains remaining along with small mineral assemblage. Begin final concentration of shards. >> LO-FRANTZ NEXT.

0.6A+8ºM: dark brown shards, altered/devitrified grains, and heavies.
0.6A+8ºNM: ~100% shards, including minor population of microphenocrystic shards. Sample purity is fine for probe analysis. >> PROBE NEXT (11 Jan 2007).

Population 1: This population is the major compositional mode. Fifteen glass shards representing this population show a moderate degree of hydration and high levels of iron, magnesium, manganese, and titanium. Other than a good correlation (~0.97 similarity coefficient, with and without alkalies) with population 2 in this sample, there is no good match (≥0.95 similarity coefficient) with samples in the USGS tephra geochemistry database (see recalculated data and list of best matches; Tables 3, 4). However, this population does exhibit affinities with Cascade tephra from the Klamath, Pringle Falls, and Summer Lake areas. Andrei Sarna-Wojcicki , USGS, Emeritus, personal communication) suggests another possibility, which is that this sample may be derived from a Mexican volcanic source area. Investigating the work done on La Primavera Volcano, a large rhyolitic volcano near Guadalajara that has erupted numerous times during the Quaternary, might shed some more light on the age and eruptive origin of this tephra.

Population 2: Population 2 is the minor compositional mode, has higher iron, magnesium, and titanium values than population 1 (Figure 1), and is also relatively hydrated. The best correlation (~0.97 similarity coefficient, with and without alkalies) is to population 1 of this sample (Tables 5, 6). Again, there is no match to another sample in our extensive database. However, this mode also shows similarities to Cascade tephra.



Figures 4 and 5. Location map and photograph of field sample number CW-3-16-06-3.

## CONCLUSIONS

Of ten tephra samples collected, two were submitted for glass geochemical analysis. Only one of the submitted samples contained sufficient quantities of glass shards to be analyzed. This analysis shows that the California Wash tephra is not correlative with the Huckleberry Ridge Ash. No correlation was made with other tephras in the USGS database. It is possible this tephra was derived from an eruption in Mexico.

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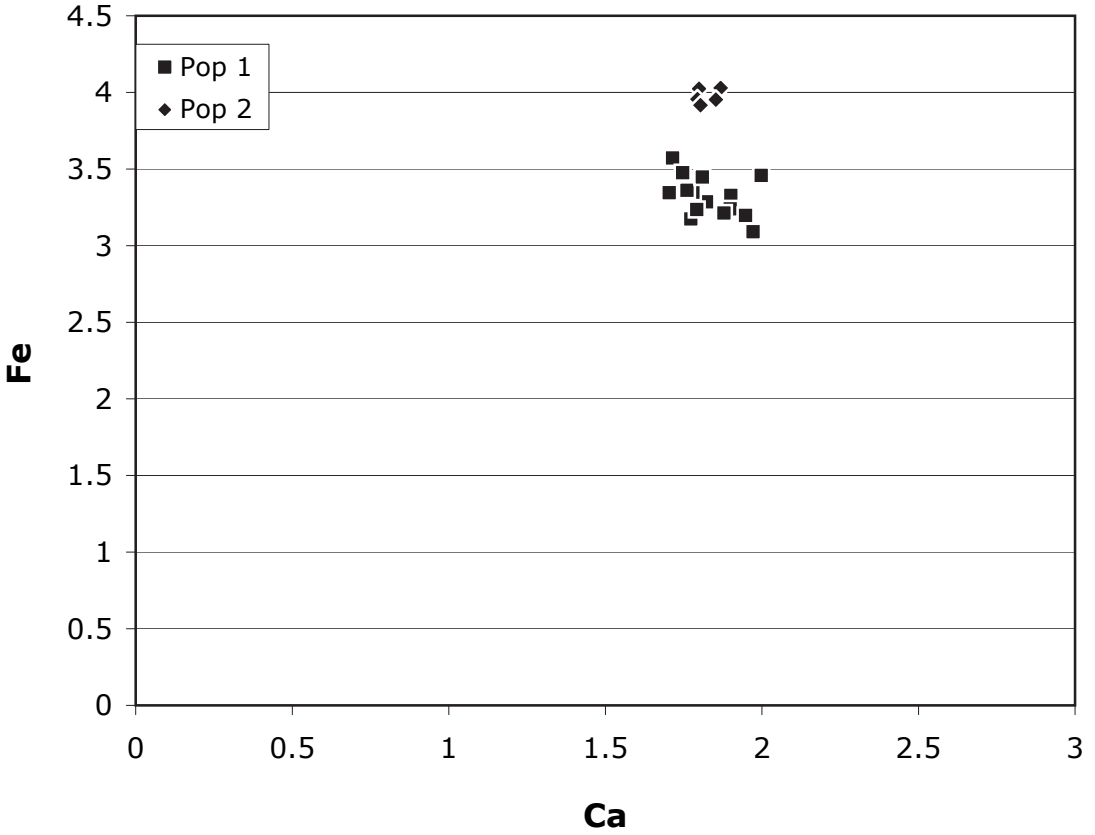
**Figure 6. AZGS-031606-CW3, Ca vs. Fe**



| Table 1. Thin section tephra samples, 2006 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Number** | **Waypoint** | **Zone** | **UTME (NAD83)** | **UMTN (NAD 83)** | **Date Collected** | **Geographic Location** | **7.5' Quadrangle** | **Comments** | **Glass shards in thin section** | **sent to USGS** |
| DW-10-25-05-2A | AY06.0842 | 12R | 575799 | 3532357 | 25-Oct-05 | Dragoon Wash | St. David | Dragoon Wash | No | |
| DW-10-25-05-2B | AY06.0842 | 12R | 575799 | 3532357 | 26-Oct-05 | Dragoon Wash | St. David | Wash | No | |
| CW-3-16-06-1 | AY06.0322 | 12 R | 569481 | 3521095 | 16-Mar-06 | California Wash | McGrew Springs | First ash looks pretty reworked. Lowest in section?? | No | |
| CW-3-16-06-2 | AY06.0323 | 12 R | 569341 | 3521219 | 16-Mar-06 | California Wash | McGrew Springs | White ash from near top of ridge. | Yes | |
| CW-3-16-06-3 | AY06.0324 | 12 R | 569308 | 3521102 | 16-Mar-06 | California Wash | McGrew Springs | Brown ash. Below white ash. Above re-worked ash? Dated K/Ar 2.5±0.4 Ma (Scarborough, 1975) | Yes | Yes |
| DW-3-16-06-4 | AY06.0325 | 12 R | 575925 | 3532122 | 16-Mar-06 | Dragoon Wash | St. David | Upper ash bed/carb/ls bed. Collected near DW-10-25-05-2A but on the south side of the ridge road. | No | |
| PR-4-19-06-1 | AY06.0391 | 12 R | 566167 | 3533133 | 19-Apr-06 | Post Ranch | Benson | Lower of the two white beds. In faulted area. Collected from wash south of tusk wash. | Yes | |
| | AY06.0392 | 12 R | 566014 | 3533190 | 19-Apr-06 | Post Ranch | Benson | Photo shot of chnl sands | No | |
| PR-4-19-06-2 | AY06.0393 | 12 R | 565974 | 3533127 | 19-Apr-06 | Post Ranch | Benson | Upper white bed. West of faulted area? Two densities in the ash. Upper part was very hard. Collected from lower, more ashy/punky part. In wash tusk wash. | No | |
| PR-4-19-06-3 | AY06.0394 | 12 R | 566124 | 3533308 | 19-Apr-06 | Post Ranch | Benson | Lower of the two white beds. Turns out to be middle ash in this location. Ash 4 collected just below this location at the base of the ridge, about 4 m above PR-4-19-06-4. UTM Cords **VERY APPROXIMATE!** | No | |
| PR-4-19-06-4 | | 12 R | 566111 | 3533320 | 19-Apr-06 | Post Ranch | Benson | 06-3. This is most likely Gray's 5' thick gray green tuff. If this is the tuff that was dated "below the Benson Fauna horizon at Post Ranch" (Johnson, 1975) it is zircon fission-track dated to 3.1±0.7 Ma. | Yes | Yes |

| Table 2. Electron-microprobe analyses of major elements in tephra glass fragments | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **AZGS-031606-CW3 (California Wash sample)** | | | | | | | | | | | |
| **(CW-3-16-06-3 is original field sample number, converted to AZGS-031606-CW3 by USGS)** | | | | | | | | | | | |
| **No.** | **$Na_2O$** | **MgO** | **$Al_2O_3$** | **$SiO_2$** | **$K_2O$** | **CaO** | **$TiO_2$** | **MnO** | **FeO** | **Total** | |
| **Population 1** | | | | | | | | | | | |
| 631 | 3.083 | 0.483 | 13.008 | 68.574 | 2.787 | 1.901 | 0.465 | 0.115 | 3.328 | 93.744 | AZGS-031606-CW3 T545-7 1 |
| 632 | 3.31 | 0.467 | 13.232 | 68.761 | 2.715 | 1.823 | 0.472 | 0.078 | 3.286 | 94.144 | AZGS-031606-CW3 T545-7 2 |
| 633 | 3.236 | 0.451 | 13.118 | 67.751 | 2.776 | 1.899 | 0.39 | 0.066 | 3.24 | 92.927 | AZGS-031606-CW3 T545-7 3 |
| 634 | 3.147 | 0.458 | 13.103 | 68.04 | 2.767 | 1.998 | 0.481 | 0.057 | 3.458 | 93.509 | AZGS-031606-CW3 T545-7 4 |
| 635 | 2.557 | 0.499 | 12.916 | 66.055 | 3.048 | 1.773 | 0.491 | 0.055 | 3.174 | 90.568 | AZGS-031606-CW3 T545-7 5 |
| 636 | 3.171 | 0.419 | 13.303 | 69.657 | 2.714 | 1.972 | 0.536 | 0.095 | 3.091 | 94.958 | AZGS-031606-CW3 T545-7 6 |
| 637 | 3.155 | 0.445 | 13.21 | 68.134 | 2.821 | 1.715 | 0.461 | 0.074 | 3.572 | 93.587 | AZGS-031606-CW3 T545-7 7 |
| 638 | 3.336 | 0.435 | 13.109 | 68.49 | 2.907 | 1.78 | 0.433 | 0.08 | 3.348 | 93.918 | AZGS-031606-CW3 T545-7 8 |
| 639 | 3.323 | 0.466 | 12.981 | 67.796 | 2.753 | 1.704 | 0.43 | 0.068 | 3.345 | 92.866 | AZGS-031606-CW3 T545-7 9 |
| 640 | 3.359 | 0.455 | 13.135 | 68.16 | 2.808 | 1.761 | 0.48 | 0.07 | 3.361 | 93.589 | AZGS-031606-CW3 T545-7 10 |
| 641 | 3.173 | 0.442 | 13.186 | 69.637 | 2.846 | 1.747 | 0.493 | 0.038 | 3.476 | 95.038 | AZGS-031606-CW3 T545-7 11 |
| 647 | 3.16 | 0.459 | 12.986 | 67.61 | 2.824 | 1.879 | 0.457 | 0.079 | 3.213 | 92.667 | AZGS-031606-CW3 T545-7 17 |
| 648 | 3.436 | 0.47 | 13.235 | 68.151 | 2.652 | 1.792 | 0.476 | 0.097 | 3.236 | 93.545 | AZGS-031606-CW3 T545-7 18 |
| 649 | 3.258 | 0.469 | 13.037 | 68.064 | 2.817 | 1.948 | 0.472 | 0.051 | 3.197 | 93.313 | AZGS-031606-CW3 T545-7 19 |
| 650 | 3.267 | 0.46 | 13.118 | 68.63 | 2.815 | 1.81 | 0.521 | 0.063 | 3.448 | 94.132 | AZGS-031606-CW3 T545-7 20 |
| **Population 2** | | | | | | | | | | | |
| 642 | 3.085 | 0.445 | 13.231 | 68.925 | 2.816 | 1.868 | 0.438 | 0.072 | 4.029 | 94.909 | AZGS-031606-CW3 T545-7 12 |
| 645 | 2.977 | 0.483 | 13.114 | 67.18 | 3.118 | 1.799 | 0.464 | 0.048 | 4.024 | 93.207 | AZGS-031606-CW3 T545-7 15 |
| 646 | 3.249 | 0.491 | 13.173 | 69.803 | 2.76 | 1.853 | 0.542 | 0.089 | 3.953 | 95.913 | AZGS-031606-CW3 T545-7 16 |
| 643 | 3.328 | 0.457 | 13.292 | 67.953 | 2.616 | 1.794 | 0.466 | 0.031 | 3.956 | 93.893 | AZGS-031606-CW3 T545-7 13 |
| 644 | 3.304 | 0.476 | 13.127 | 68.201 | 2.604 | 1.804 | 0.48 | 0.064 | 3.916 | 93.976 | AZGS-031606-CW3 T545-7 14 |
| | | | | | | | | | | | |
| **AZGS-031606-CW3 T545-7 3** | | | | | | | | | | | |
| **Population 1** | | | | | | | | | | | |
| Mean | 3.198 | 0.459 | 13.112 | 68.234 | 2.803 | 1.833 | 0.471 | 0.072 | 3.318 | 93.500 | |
| Standard Deviation | 0.202 | 0.019 | 0.110 | 0.856 | 0.091 | 0.094 | 0.036 | 0.020 | 0.131 | 1.056 | |
| Range | 0.879 | 0.080 | 0.387 | 3.602 | 0.396 | 0.294 | 0.146 | 0.077 | 0.481 | 4.470 | |
| Minimum | 2.557 | 0.419 | 12.916 | 66.055 | 2.652 | 1.704 | 0.390 | 0.038 | 3.091 | 90.568 | |
| Maximum | 3.436 | 0.499 | 13.303 | 69.657 | 3.048 | 1.998 | 0.536 | 0.115 | 3.572 | 95.038 | |
| Count | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | |
| Confidence Level (95%) | 0.112 | 0.011 | 0.061 | 0.474 | 0.051 | 0.052 | 0.020 | 0.011 | 0.073 | 0.585 | |
| **Population 2** | | | | | | | | | | | |
| Mean | 3.189 | 0.470 | 13.187 | 68.412 | 2.783 | 1.824 | 0.478 | 0.061 | 3.976 | 94.380 | |
| Standard Deviation | 0.152 | 0.019 | 0.074 | 0.996 | 0.208 | 0.034 | 0.039 | 0.022 | 0.049 | 1.050 | |
| Range | 0.351 | 0.046 | 0.178 | 2.623 | 0.514 | 0.074 | 0.104 | 0.058 | 0.113 | 2.706 | |
| Minimum | 2.977 | 0.445 | 13.114 | 67.180 | 2.604 | 1.794 | 0.438 | 0.031 | 3.916 | 93.207 | |
| Maximum | 3.328 | 0.491 | 13.292 | 69.803 | 3.118 | 1.868 | 0.542 | 0.089 | 4.029 | 95.913 | |
| Count | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | |
| Confidence Level (95.0%) | 0.188 | 0.024 | 0.092 | 1.237 | 0.259 | 0.043 | 0.048 | 0.028 | 0.061 | 1.303 | |

**Table 3. Listing of 37 closest matches for COMP. NO. 5514 for elements: Mg, Al, Si, Ca, Ti, Fe**

Date of Update: 1/23/07

Analyses in weght percent normalized to 100% total

| | C. No | Sample Number | Date | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | MnO | CaO | $TiO_2$ | $Na_2O$ | $K_2O$ | Total, R | Sim. Coeff. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5514 | AZGS-031606-CW3 T545-7(pop1) | 1/17/2007 | 72.69 | 13.97 | 3.93 | 0.49 | 0.08 | 1.95 | 0.5 | 3.41 | 2.99 | 100.01 | 1 |
| 2 | 5515 | AZGS-031606-CW3 T545-7(pop2) | 1/17/2007 | 72.15 | 13.91 | 4.66 | 0.5 | 0.06 | 1.92 | 0.5 | 3.36 | 2.93 | 99.99 | 0.966 |
| 3 | 1119 | 61484-50 ASW T83-8 | 10/12/1984 | 71.24 | 14.27 | 3.44 | 0.5 | 0.09 | 1.73 | 0.51 | 5.21 | 3 | 99.99 | 0.947 |
| 4 | 2067 | PF-88-I T170-14 | 9/3/1988 | 71.73 | 14.87 | 3.59 | 0.5 | 0.11 | 1.73 | 0.48 | 4.38 | 2.62 | 100.01 | 0.9445 |
| 5 | 2031 | PF-88-D T169-1 | 10/2/1988 | 70.09 | 15.22 | 3.61 | 0.51 | 0.12 | 1.76 | 0.51 | 5.71 | 2.47 | 100 | 0.9407 |
| 6 | 911 | DR-16 | | 70.34 | 14.95 | 3.52 | 0.5 | 0.09 | 1.67 | 0.5 | 5.42 | 3.01 | 100 | 0.939 |
| 7 | 2100 | PF-88-D (2) T173-5 | 9/28/1988 | 69.96 | 15.61 | 3.62 | 0.5 | 0.1 | 1.8 | 0.47 | 5.49 | 2.45 | 100 | 0.9369 |
| 8 | 834 | GS-79 | | 70.22 | 14.85 | 3.49 | 0.5 | 0.09 | 1.63 | 0.5 | 5.52 | 3.21 | 100.01 | 0.9351 |
| 9 | 3377 | ELEG-3 maj T315-10 | 11/23/1994 | 70.9 | 14.59 | 3.4 | 0.57 | 0.05 | 1.97 | 0.48 | 4.68 | 3.36 | 100 | 0.9346 |
| 10 | 2867 | PF-HB-a | | 70.22 | 15.15 | 3.59 | 0.47 | 0 | 1.72 | 0.48 | 5.85 | 2.51 | 99.99 | 0.9338 |
| 11 | 2034 | PF-88-K T169-4 | 10/2/1988 | 69.76 | 15.33 | 3.64 | 0.58 | 0.1 | 1.91 | 0.51 | 5.82 | 2.35 | 100 | 0.9336 |
| 12 | 1552 | PI-OR (1.0CM) T126-9 | 7/17/1986 | 70.39 | 14.85 | 3.65 | 0.55 | 0.13 | 1.79 | 0.53 | 5.65 | 2.47 | 100.01 | 0.9317 |
| 13 | 3376 | ELEG-2 T315-9 | 11/23/1994 | 70.71 | 14.48 | 3.4 | 0.56 | 0.03 | 1.92 | 0.54 | 4.88 | 3.46 | 99.98 | 0.9314 |
| 14 | 833 | GS-78 | | 70.05 | 15.05 | 3.43 | 0.5 | 0.07 | 1.68 | 0.49 | 5.42 | 3.31 | 100 | 0.931 |
| 15 | 2724 | BUR871.11 | | 71.98 | 15.22 | 3.54 | 0.6 | 0.1 | 1.91 | 0.49 | 3.19 | 2.97 | 100 | 0.9308 |
| 16 | 3726 | PF-93-AL T345-4 | Nov-96 | 70.22 | 15.62 | 3.54 | 0.51 | 0.1 | 1.75 | 0.48 | 5.33 | 2.46 | 100.01 | 0.9299 |
| 17 | 2033 | PF-88-H T169-3 | 10/2/1988 | 70.53 | 15.04 | 3.28 | 0.49 | 0.1 | 1.68 | 0.51 | 5.95 | 2.41 | 99.99 | 0.9293 |
| 18 | 1002 | RC-25 | | 70.19 | 15.06 | 3.46 | 0.51 | 0.09 | 1.66 | 0.49 | 5.52 | 3.01 | 99.99 | 0.9276 |
| 19 | 3553 | PF-93-A T328-2 | 8/30/1995 | 69.38 | 15.71 | 3.63 | 0.53 | 0.12 | 1.78 | 0.48 | 5.95 | 2.42 | 100 | 0.9275 |
| 20 | 3109 | DLS-674A MAJ(HIFE) T289-8 | 11/4/1993 | 69.85 | 15.2 | 4.73 | 0.53 | 0.15 | 1.89 | 0.53 | 4.41 | 2.71 | 100 | 0.9247 |
| 21 | 857 | LM-11 | | 69.53 | 15.05 | 4.69 | 0.47 | 0.14 | 1.84 | 0.56 | 5.52 | 2.21 | 100.01 | 0.9197 |
| 22 | 676 | BUR-872, T59-B1 | xx/xx/xx | 70.15 | 15.13 | 3.39 | 0.57 | 0.08 | 1.88 | 0.47 | 5.4 | 2.94 | 100.01 | 0.9191 |
| 23 | 2337 | K-AH-1 T194-5 | 7/20/1989 | 74.14 | 13.29 | 2.65 | 0.47 | 0.09 | 1.98 | 0.53 | 4.08 | 2.77 | 100 | 0.9156 |
| 24 | 5110 | MRM62-02 T500-3 | 6/23/2003 | 71.82 | 14.48 | 3.9 | 0.39 | 0.09 | 1.74 | 0.43 | 4.02 | 3.13 | 100 | 0.9156 |
| 25 | 931 | DR-40 | | 69.3 | 15.37 | 3.68 | 0.55 | 0.11 | 1.86 | 0.59 | 6.13 | 2.41 | 100 | 0.9151 |
| 26 | 881 | CB-7 | | 72.38 | 14.56 | 2.49 | 0.5 | 0.05 | 1.8 | 0.49 | 4.62 | 3.11 | 100 | 0.912 |
| 27 | 5452 | LBS-L-071205-djk T537-4(Pop1) | 2/14/2006 | 74.58 | 15.7 | 3.93 | 0.62 | 0.1 | 2.09 | 0.57 | 0.74 | 1.67 | 100 | 0.9108 |
| 28 | 5428 | SV-A02(all) T529-10 | 8/9/2005 | 71.12 | 15.35 | 2.66 | 0.45 | 0.06 | 1.95 | 0.51 | 4.54 | 3.37 | 100.01 | 0.9107 |
| 29 | 1094 | 61384-24 ASW T81-12 | 9/4/1984 | 70.95 | 14.7 | 3.2 | 0.56 | 0.1 | 1.82 | 0.55 | 3.94 | 4.16 | 99.98 | 0.9097 |
| 30 | 1467 | ZARAGOZA 48 T115-10 | 1/27/1986 | 69.28 | 15.34 | 3.1 | 0.5 | 0.08 | 1.68 | 0.48 | 5.57 | 3.97 | 100 | 0.909 |
| 31 | 1288 | Tulelake 2382 T100-1 | 7/2/1985 | 72.17 | 14.51 | 2.63 | 0.49 | 0.05 | 1.73 | 0.47 | 4.64 | 3.31 | 100 | 0.9087 |
| 32 | 883 | CB-9 | | 72.3 | 14.54 | 2.46 | 0.52 | 0.05 | 1.8 | 0.5 | 4.71 | 3.11 | 99.99 | 0.9078 |
| 33 | 882 | CB-8 | | 72.63 | 14.47 | 2.41 | 0.51 | 0.05 | 1.8 | 0.49 | 4.52 | 3.11 | 99.99 | 0.907 |
| 34 | 813 | GS-57 | | 72.38 | 14.74 | 2.38 | 0.49 | 0.03 | 1.77 | 0.49 | 4.71 | 3.01 | 100 | 0.9061 |
| 35 | 3432 | CRB #204 5/94 | May-94 | 71.61 | 14.66 | 2.58 | 0.57 | 0.05 | 1.95 | 0.51 | 4.86 | 3.22 | 100.01 | 0.9058 |
| 36 | 3727 | PF-93-AU T345-5 | Nov-96 | 70.23 | 15.6 | 3.48 | 0.53 | 0.11 | 1.68 | 0.45 | 5.44 | 2.47 | 99.99 | 0.9055 |
| 37 | 3415 | CRB #360 11/94 | Nov-94 | 72.3 | 14.29 | 2.5 | 0.52 | 0.03 | 1.75 | 0.49 | 4.85 | 3.26 | 99.99 | 0.9047 |

**Table 4. Listing of 37 closest matches for COMP. NO. 5514 for elements: Na, Mg, Al, Si, K , Ca, Ti, Fe**

Date of Update: 1/23/07

Analyses in weght percent normalized to 100% total

| | C. No | Sample Number | Date | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | MnO | CaO | $TiO_2$ | $Na_2O$ | $K_2O$ | Total, R | Sim. Coeff. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5514 | AZGS-031606-CW3 T545-7(pop1) | 1/17/2007 | 72.69 | 13.97 | 3.93 | 0.49 | 0.08 | 1.95 | 0.5 | 3.41 | 2.99 | 100.01 | 1 |
| 2 | 5515 | AZGS-031606-CW3 T545-7(pop2) | 1/17/2007 | 72.15 | 13.91 | 4.66 | 0.5 | 0.06 | 1.92 | 0.5 | 3.36 | 2.93 | 99.99 | 0.9702 |
| 3 | 2724 | BUR871.11 | | 71.98 | 15.22 | 3.54 | 0.6 | 0.1 | 1.91 | 0.49 | 3.19 | 2.97 | 100 | 0.9392 |
| 4 | 1119 | 61484-50 ASW T83-8 | 10/12/1984 | 71.24 | 14.27 | 3.44 | 0.5 | 0.09 | 1.73 | 0.51 | 5.21 | 3 | 99.99 | 0.9166 |
| 5 | 2067 | PF-88-I T170-14 | 9/3/1988 | 71.73 | 14.87 | 3.59 | 0.5 | 0.11 | 1.73 | 0.48 | 4.38 | 2.62 | 100.01 | 0.9152 |
| 6 | 5110 | MRM62-02 T500-3 | 6/23/2003 | 71.82 | 14.48 | 3.9 | 0.39 | 0.09 | 1.74 | 0.43 | 4.02 | 3.13 | 100 | 0.9121 |
| 7 | 3776 | 942-227 | | 74.55 | 14.07 | 2.6 | 0.48 | 0.05 | 1.74 | 0.44 | 3.14 | 2.93 | 100 | 0.9103 |
| 8 | 911 | DR-16 | | 70.34 | 14.95 | 3.52 | 0.5 | 0.09 | 1.67 | 0.5 | 5.42 | 3.01 | 100 | 0.9071 |
| 9 | 2337 | K-AH-1 T194-5 | 7/20/1989 | 74.14 | 13.29 | 2.65 | 0.47 | 0.09 | 1.98 | 0.53 | 4.08 | 2.77 | 100 | 0.907 |
| 10 | 3109 | DLS-674A MAJ(HIFE) T289-8 | 11/4/1993 | 69.85 | 15.2 | 4.73 | 0.53 | 0.15 | 1.89 | 0.53 | 4.41 | 2.71 | 100 | 0.9035 |
| 11 | 3377 | ELEG-3 maj T315-10 | 11/23/1994 | 70.9 | 14.59 | 3.4 | 0.57 | 0.05 | 1.97 | 0.48 | 4.68 | 3.36 | 100 | 0.9033 |
| 12 | 1002 | RC-25 | | 70.19 | 15.06 | 3.46 | 0.51 | 0.09 | 1.66 | 0.49 | 5.52 | 3.01 | 99.99 | 0.8971 |
| 13 | 881 | CB-7 | | 72.38 | 14.56 | 2.49 | 0.5 | 0.05 | 1.8 | 0.49 | 4.62 | 3.11 | 100 | 0.8964 |
| 14 | 4485 | AL-E2 T415-10 | 8/28/1999 | 72.89 | 13.58 | 3.26 | 0.53 | 0.05 | 1.82 | 0.68 | 3.79 | 3.41 | 100.01 | 0.8961 |
| 15 | 834 | GS-79 | | 70.22 | 14.85 | 3.49 | 0.5 | 0.09 | 1.63 | 0.5 | 5.52 | 3.21 | 100.01 | 0.895 |
| 16 | 882 | CB-8 | | 72.63 | 14.47 | 2.41 | 0.51 | 0.05 | 1.8 | 0.49 | 4.52 | 3.11 | 99.99 | 0.8947 |
| 17 | 3790 | 8-19-75 (10) T350-4 | Dec-96 | 69.39 | 14.86 | 5.12 | 0.49 | 0.11 | 2.53 | 0.46 | 4.12 | 2.92 | 100 | 0.8947 |
| 18 | 813 | GS-57 | | 72.38 | 14.74 | 2.38 | 0.49 | 0.03 | 1.77 | 0.49 | 4.71 | 3.01 | 100 | 0.8943 |
| 19 | 3376 | ELEG-2 T315-9 | 11/23/1994 | 70.71 | 14.48 | 3.4 | 0.56 | 0.03 | 1.92 | 0.54 | 4.88 | 3.46 | 99.98 | 0.8939 |
| 20 | 883 | CB-9 | | 72.3 | 14.54 | 2.46 | 0.52 | 0.05 | 1.8 | 0.5 | 4.71 | 3.11 | 99.99 | 0.8915 |
| 21 | 676 | BUR-872, T59-B1 | xx/xx/xx | 70.15 | 15.13 | 3.39 | 0.57 | 0.08 | 1.88 | 0.47 | 5.4 | 2.94 | 100.01 | 0.8912 |
| 22 | 833 | GS-78 | | 70.05 | 15.05 | 3.43 | 0.5 | 0.07 | 1.68 | 0.49 | 5.42 | 3.31 | 100 | 0.8898 |
| 23 | 1067 | 324-M-RT T76-2 | 7/28/1984 | 71.86 | 14.99 | 2.43 | 0.49 | 0.1 | 1.96 | 0.44 | 4.77 | 2.96 | 100 | 0.8898 |
| 24 | 3831 | CD1-11.27M T354-3 | Jan-97 | 73.24 | 14.62 | 3.06 | 0.61 | 0.06 | 1.9 | 0.62 | 2.83 | 3.06 | 100 | 0.8897 |
| 25 | 951 | DR-63 | | 74.27 | 13.93 | 2.16 | 0.48 | 0.04 | 1.87 | 0.43 | 4.01 | 2.81 | 100 | 0.8893 |
| 26 | 734 | S-13 | | 73.48 | 14.15 | 2.26 | 0.5 | 0.04 | 1.89 | 0.45 | 4.42 | 2.81 | 100 | 0.889 |
| 27 | 5428 | SV-A02(all) T529-10 | 8/9/2005 | 71.12 | 15.35 | 2.66 | 0.45 | 0.06 | 1.95 | 0.51 | 4.54 | 3.37 | 100.01 | 0.8878 |
| 28 | 5429 | SV-A02(Pop1) T529-10 | 8/9/2005 | 72.17 | 15.2 | 2.54 | 0.51 | 0.06 | 1.88 | 0.43 | 4.32 | 2.9 | 100.01 | 0.8878 |
| 29 | 3777 | 942-360 major | | 74.51 | 14.71 | 2.25 | 0.49 | 0.06 | 1.71 | 0.45 | 3.12 | 2.7 | 100 | 0.8866 |
| 30 | 1288 | Tulelake 2382 T100-1 | 7/2/1985 | 72.17 | 14.51 | 2.63 | 0.49 | 0.05 | 1.73 | 0.47 | 4.64 | 3.31 | 100 | 0.8863 |
| 31 | 3681 | EL-64-PV T339-8 | Nov-96 | 72.48 | 14.35 | 2.7 | 0.64 | 0.08 | 2 | 0.57 | 4.15 | 3.03 | 100 | 0.8855 |
| 32 | 3682 | EL-64-PV #2 T339-8 | Nov-96 | 72.42 | 14.25 | 2.63 | 0.63 | 0.08 | 1.95 | 0.56 | 4.51 | 2.99 | 100.02 | 0.8841 |
| 33 | 3440 | BUR-498.11R | | 72.09 | 15.36 | 2.66 | 0.52 | 0.08 | 1.81 | 0.4 | 3.98 | 3.1 | 100 | 0.8837 |
| 34 | 964 | DR-77 | | 73.91 | 13.96 | 2.2 | 0.5 | 0.04 | 1.93 | 0.43 | 4.32 | 2.71 | 100 | 0.8835 |
| 35 | 2031 | PF-88-D T169-1 | 10/2/1988 | 70.09 | 15.22 | 3.61 | 0.51 | 0.12 | 1.76 | 0.51 | 5.71 | 2.47 | 100 | 0.8835 |
| 36 | 3432 | CRB #204 5/94 | May-94 | 71.61 | 14.66 | 2.58 | 0.57 | 0.05 | 1.95 | 0.51 | 4.86 | 3.22 | 100.01 | 0.8831 |
| 37 | 2100 | PF-88-D (2) T173-5 | 9/28/1988 | 69.96 | 15.61 | 3.62 | 0.5 | 0.1 | 1.8 | 0.47 | 5.49 | 2.45 | 100 | 0.8828 |

**Tabe 5. Listing of 37 closest matches for COMP. NO. 5515 for elements: Mg, Al, Si, Ca, Ti, Fe**

Date of Update: 1/23/07

Analyses in weght percent normalized to 100% total

| | C. No | Sample Number | Date | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | MnO | CaO | $TiO_2$ | $Na_2O$ | $K_2O$ | Total, R | Sim. Coeff. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5515 | AZGS-031606-CW3 T545-7(pop2) | 1/17/2007 | 72.15 | 13.91 | 4.66 | 0.5 | 0.06 | 1.92 | 0.5 | 3.36 | 2.93 | 99.99 | 1 |
| 2 | 5514 | AZGS-031606-CW3 T545-7(pop1) | 1/17/2007 | 72.69 | 13.97 | 3.93 | 0.49 | 0.08 | 1.95 | 0.5 | 3.41 | 2.99 | 100.01 | 0.966 |
| 3 | 3109 | DLS-674A MAJ(HIFE) T289-8 | 11/4/1993 | 69.85 | 15.2 | 4.73 | 0.53 | 0.15 | 1.89 | 0.53 | 4.41 | 2.71 | 100 | 0.9566 |
| 4 | 857 | LM-11 | | 69.53 | 15.05 | 4.69 | 0.47 | 0.14 | 1.84 | 0.56 | 5.52 | 2.21 | 100.01 | 0.9455 |
| 5 | 3366 | MA-359 T315-2 | 11/23/1994 | 67.96 | 15.44 | 4.59 | 0.54 | 0.1 | 1.87 | 0.58 | 5.15 | 3.76 | 99.99 | 0.9316 |
| 6 | 1119 | 61484-50 ASW T83-8 | 10/12/1984 | 71.24 | 14.27 | 3.44 | 0.5 | 0.09 | 1.73 | 0.51 | 5.21 | 3 | 99.99 | 0.9303 |
| 7 | 2067 | PF-88-I T170-14 | 9/3/1988 | 71.73 | 14.87 | 3.59 | 0.5 | 0.11 | 1.73 | 0.48 | 4.38 | 2.62 | 100.01 | 0.9268 |
| 8 | 42 | BU, T25-3 | | 68.25 | 14.85 | 4.76 | 0.54 | 0.17 | 1.98 | 0.63 | 6.63 | 2.19 | 100 | 0.9252 |
| 9 | 2031 | PF-88-D T169-1 | 10/2/1988 | 70.09 | 15.22 | 3.61 | 0.51 | 0.12 | 1.76 | 0.51 | 5.71 | 2.47 | 100 | 0.9229 |
| 10 | 911 | DR-16 | | 70.34 | 14.95 | 3.52 | 0.5 | 0.09 | 1.67 | 0.5 | 5.42 | 3.01 | 100 | 0.9218 |
| 11 | 2100 | PF-88-D (2) T173-5 | 9/28/1988 | 69.96 | 15.61 | 3.62 | 0.5 | 0.1 | 1.8 | 0.47 | 5.49 | 2.45 | 100 | 0.9192 |
| 12 | 834 | GS-79 | | 70.22 | 14.85 | 3.49 | 0.5 | 0.09 | 1.63 | 0.5 | 5.52 | 3.21 | 100.01 | 0.918 |
| 13 | 2034 | PF-88-K T169-4 | 10/2/1988 | 69.76 | 15.33 | 3.64 | 0.58 | 0.1 | 1.91 | 0.51 | 5.82 | 2.35 | 100 | 0.9154 |
| 14 | 3376 | ELEG-2 T315-9 | 11/23/1994 | 70.71 | 14.48 | 3.4 | 0.56 | 0.03 | 1.92 | 0.54 | 4.88 | 3.46 | 99.98 | 0.9148 |
| 15 | 833 | GS-78 | | 70.05 | 15.05 | 3.43 | 0.5 | 0.07 | 1.68 | 0.49 | 5.42 | 3.31 | 100 | 0.9144 |
| 16 | 1552 | PI-OR (1.0CM) T126-9 | 7/17/1986 | 70.39 | 14.85 | 3.65 | 0.55 | 0.13 | 1.79 | 0.53 | 5.65 | 2.47 | 100.01 | 0.9134 |
| 17 | 2724 | BUR871.11 | | 71.98 | 15.22 | 3.54 | 0.6 | 0.1 | 1.91 | 0.49 | 3.19 | 2.97 | 100 | 0.9132 |
| 18 | 3377 | ELEG-3 maj T315-10 | 11/23/1994 | 70.9 | 14.59 | 3.4 | 0.57 | 0.05 | 1.97 | 0.48 | 4.68 | 3.36 | 100 | 0.9129 |
| 19 | 3726 | PF-93-AL T345-4 | Nov-96 | 70.22 | 15.62 | 3.54 | 0.51 | 0.1 | 1.75 | 0.48 | 5.33 | 2.46 | 100.01 | 0.9125 |
| 20 | 3790 | 8-19-75 (10) T350-4 | Dec-96 | 69.39 | 14.86 | 5.12 | 0.49 | 0.11 | 2.53 | 0.46 | 4.12 | 2.92 | 100 | 0.9111 |
| 21 | 1002 | RC-25 | | 70.19 | 15.06 | 3.46 | 0.51 | 0.09 | 1.66 | 0.49 | 5.52 | 3.01 | 99.99 | 0.9107 |
| 22 | 2867 | PF-HB-a | | 70.22 | 15.15 | 3.59 | 0.47 | 0 | 1.72 | 0.48 | 5.85 | 2.51 | 99.99 | 0.9096 |
| 23 | 3553 | PF-93-A T328-2 | 8/30/1995 | 69.38 | 15.71 | 3.63 | 0.53 | 0.12 | 1.78 | 0.48 | 5.95 | 2.42 | 100 | 0.9094 |
| 24 | 2033 | PF-88-H T169-3 | 10/2/1988 | 70.53 | 15.04 | 3.28 | 0.49 | 0.1 | 1.68 | 0.51 | 5.95 | 2.41 | 99.99 | 0.9069 |
| 25 | 676 | BUR-872, T59-B1 | xx/xx/xx | 70.15 | 15.13 | 3.39 | 0.57 | 0.08 | 1.88 | 0.47 | 5.4 | 2.94 | 100.01 | 0.9026 |
| 26 | 881 | CB-7 | | 72.38 | 14.56 | 2.49 | 0.5 | 0.05 | 1.8 | 0.49 | 4.62 | 3.11 | 100 | 0.9007 |
| 27 | 883 | CB-9 | | 72.3 | 14.54 | 2.46 | 0.52 | 0.05 | 1.8 | 0.5 | 4.71 | 3.11 | 99.99 | 0.8969 |
| 28 | 931 | DR-40 | | 69.3 | 15.37 | 3.68 | 0.55 | 0.11 | 1.86 | 0.59 | 6.13 | 2.41 | 100 | 0.8968 |
| 29 | 882 | CB-8 | | 72.63 | 14.47 | 2.41 | 0.51 | 0.05 | 1.8 | 0.49 | 4.52 | 3.11 | 99.99 | 0.895 |
| 30 | 1467 | ZARAGOZA 48 T115-10 | 1/27/1986 | 69.28 | 15.34 | 3.1 | 0.5 | 0.08 | 1.68 | 0.48 | 5.57 | 3.97 | 100 | 0.8945 |
| 31 | 1094 | 61384-24 ASW T81-12 | 9/4/1984 | 70.95 | 14.7 | 3.2 | 0.56 | 0.1 | 1.82 | 0.55 | 3.94 | 4.16 | 99.98 | 0.8944 |
| 32 | 3415 | CRB #360 11/94 | Nov-94 | 72.3 | 14.29 | 2.5 | 0.52 | 0.03 | 1.75 | 0.49 | 4.85 | 3.26 | 99.99 | 0.8935 |
| 33 | 2337 | K-AH-1 T194-5 | 7/20/1989 | 74.14 | 13.29 | 2.65 | 0.47 | 0.09 | 1.98 | 0.53 | 4.08 | 2.77 | 100 | 0.8917 |
| 34 | 2258 | T188-7 675-M | 5/9/1989 | 72.02 | 13.87 | 2.55 | 0.51 | 0.03 | 1.72 | 0.54 | 3.98 | 4.77 | 99.99 | 0.8908 |
| 35 | 1288 | Tulelake 2382 T100-1 | 7/2/1985 | 72.17 | 14.51 | 2.63 | 0.49 | 0.05 | 1.73 | 0.47 | 4.64 | 3.31 | 100 | 0.8906 |
| 36 | 5110 | MRM62-02 T500-3 | 6/23/2003 | 71.82 | 14.48 | 3.9 | 0.39 | 0.09 | 1.74 | 0.43 | 4.02 | 3.13 | 100 | 0.8899 |
| 37 | 3437 | CRB #140 5/94 | May-94 | 71.75 | 14.64 | 2.51 | 0.53 | 0.06 | 1.79 | 0.49 | 4.96 | 3.27 | 100 | 0.8898 |