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K-AR AGES AND GEOTHERMAL IMPLICATIONS OF YOUNG RHYOLITES IN WEST-CENTRAL UTAH

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Young silicic rocks especially rhyolites, are considered by many geologists to be potential indicators of shallow underlying magma chambers, which in turn are possible sites for geothermal resources (for example, see Smith and Shaw, 1975). As part of the geothermal energy program of the U.S. Geological Survey, 14 new K-Ar ages were determined for alkalic rhyolites from west-central Utah. Most dated samples came from rhyolites near or within regions designated by the Department of the Interior as Known Geothermal Resource Areas (KGRA's). KGRA's of Utah and locations of dated samples are shown in figure 1; modal data on dated samples are presented in table 1. K-Ar ages and analytical data are given under the section on sample descriptions.

MINERAL MOUNTAINS

Samples 1–6 were collected from rhyolites of Mineral Mountains (fig. 1), which underlie an area of about 25 km^2 along the crest and western flank of the central Mineral Mountains. These rhyolites were first mapped by Liese (1957), Earll (1957), and Condie (1960), and received recent attention from Evans and Nash (1975) and Lipman and others (1975). They overlie a granitic batholith that has been given K-Ar ages as young as 9 m.y. (Armstrong, 1970, p. 216–217). Most rhyolite occurs within or adjacent to the Roosevelt KGRA; Roosevelt Hot Springs are about 2 km west of the nearest exposed rhyolite. A discussion of the geology and recent exploration of this KGRA is given by Petersen (1975) and Berge and others (1976).

Field work (Lipman and others, unpub. data, 1976), supplemented by the ages reported here, shows that the rhyolite of the Mineral Mountains may be subdivided into three mappable units. From oldest to youngest, these consist of (1) two 100 m-thick perlite-mantled obsidian lava flows, one of which (sample 1) yielded an age of 0.8 m.y.; (2) a pyroclastic unit of bedded ash-fall tuff and nonwelded ash-flow tuff, probably at least 180 m thick and having an obsidian age of about 0.7 m.y.; and (3) at least nine perlite-mantled lava domes (maximum diameter, more than 1 km) and small lava flows of porphyritic obsidian, two of which (samples 3 and 6) have ages of about 0.5 m.y. One of the domes, at Bearskin Mountain (sample 4) in the uppermost of the three units, yielded an obsidian age of about 0.75 m.y., but hydration-rind studies (Irving Friedman, unpub. data, 1975) and fission-track studies (Glenn A. Izett, unpub. data, 1975) on this rock suggested that this dome is one of the youngest and its K-Ar age is considered to be too old. Thus sample 5 was collected from a separate dome near sample 4 at Little Bearskin Mountain, and an age on separated sanidine was determined as 0.6 m.y., which is considered a more realistic age for the domes.

BLACK ROCK DESERT

A total area of more than 50 km^2 near the southwestern edge of the basalt fields of the Black Rock Desert is underlain by rhyolite. Obsidian "apache tears" (sample 8, fig. 1) from an eroded rhyolite flow at the Cudahy Mine, about 25 km north of the Mineral Mountains, and a sanidine separate from a devitrified silicic rock (sample 9, fig. 1) of an eroded plug, South Twin Peak, about 6 km east of the Cudahy Mine, yielded nearly identical ages of about 2.35 m.y. Other rhyolitic lava flows and lithologically similar rock are widely exposed in the area.

The rhyolite of White Mountain (sample 7, fig. 1), located about 5 km north of Meadow Hot Springs and about 7 km north of Hatton Hot Springs (Mundorff, 1970), occupies an area of less than ½ km^2 and is the youngest of our ages, dated at 0.43 m.y. It is the only known Pleistocene rhyolite in a large province of alkalic basalt of the Black Rock Desert. The rhyolite of White Mountain, which contains basalt inclusions, occurs less than 1 km from the nearest exposure of basalt of the Tabernacle volcanic field, which apparently erupted during deposition of the Provo Formation of the Lake Bonneville Group, at an age estimated by Hoover (1974) at 11,000 to 12,000 years BP or less. Most of the alkalic basalt of the Black Rock Desert is believed by Condie and Barsky (1972) and by Hoover (1974) to be about 1 m.y. old or less, and some probably is Holocene.

Farther north the rhyolite lava flows of Crater Springs (sample 10, fig. 1), located at the northern edge of Fumarole Butte and about 8 km north-northwest from the Crater Springs KGRA (Mundorff, 1970), occupy an area of about 1 km^2. The rhyolites that are overlain by basaltic flows and cones have a K-Ar sanidine age of 6.9 m.y. and are comparable in age to other isolated rhyolites (Armstrong, 1970, p. 210–211; Lindsey and others, 1975) that occur within a broad east-trending mineralized structural belt, named the Deep Creek-Tintic mineral belt by Shawe and Stewart (in press).

SOUTHERN BEAVER COUNTY

Four other rhyolites (samples 11–14) lie on an east-trending structural lineament (Rowley and others, unpub. data, 1976) that is at the southern edge of another major east-trending mineral belt, the Pioche mineral belt of Shawe and Stewart (in press).

The dated samples include the rhyolite of Staats Mine (20.2 m.y.), which are domes and flows that underlie more

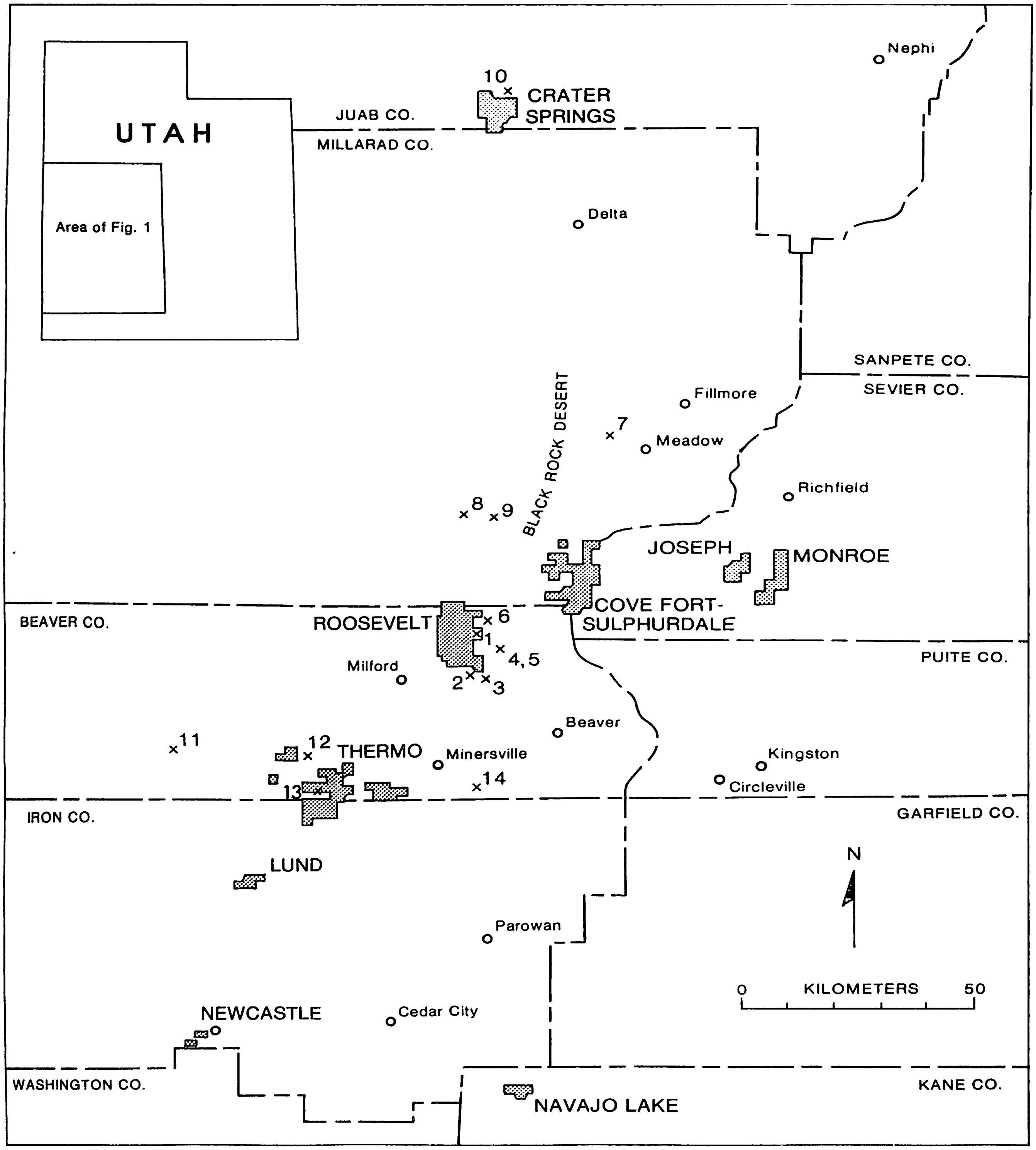

FIGURE 1. Map showing locations of Utah KGRA's (named in capital letters) and of dated rock samples. Numbers on map correspond to numbers of sample descriptions.

than 1 km^2; rhyolite of Dead Horse Reservoir (11.7 m.y.), which forms two known plugs having a combined area of less than 1 km^2; rhyolite of Thermo Hot Springs (10.3 m.y.), which is a dome that underlies an area of less than 1 km^2 (Rowley and Lipman, 1975); and rhyolite of Blue Ribbon Summit (7.4 m.y.), which consists of one or more domes that cover an area of more than 2 km^2.

Mineralized rock at the Staats Mine contains fluorine and less abundant uranium (Whelan, 1965), whereas the rhyolite of Dead Horse Reservoir is centrally located with respect to an area of extensive hydrothermal alteration. Also included in this major east-trending mineral belt are the rhyolite of the Mineral Mountains, the rhyolite of the Cudahy Mine, the rhyolite of White Mountain, and the Mount Belknap Volcanics dated at about 20 m.y. (Bassett and others, 1963).

Thus, alkalic rhyolites in west-central Utah range in age from middle Miocene (20 m.y.) to Pleistocene. Known ages of nearby alkalic basalts range in age from 13 m.y. to Holocene (Anderson and Rowley, 1975), but relatively few of these basalts have been dated and some could be older. Basalts and rhyolites thus are generally synchronous and clearly are related to basin-and-range faulting, which began no later than middle Miocene (20 m.y.) time (Anderson and Rowley, 1975). These basalts and rhyolites are an example of the bimodal basalt-rhyolite association, which has been shown to be related to extensional tectonics in the western United States (Christiansen and Lipman, 1972).

The Pleistocene ages for the following rhyolites suggest a direct tie to KGRA areas: Thus, the rhyolite of the Mineral Mountains most likely is largely responsible for the geothermal anomaly at the Roosevelt KGRA. The rhyolite of Crater Springs may supply some of the heat for the Crater Springs KGRA. The rhyolite of White Mountain may provide some geothermal energy to Hatton and Meadow Hot Springs. Rhyolite is not known in the Cove Fort area. The rhyolite of Thermo Hot Springs probably is too old to have produced the present-day geothermal anomaly.

SAMPLE DESCRIPTIONS

The following samples were analyzed by H. H. Mehnert and Violet Merritt in the U.S. Geological Survey Laboratories at Denver, Colorado. Constants used in age calculations are: $^{40}K\lambda_\epsilon = 0.581 \times 10^{-10}/y$, $^{40}K\lambda_\beta = 4.962 \times 10^{-10}/y$, $^{40}K/K = 1.167 \times 10^{-4}$. Analytical uncertainty is quoted as 2σ.

1. *DKA 3187* K-Ar
Rhyolite of Mineral Mountains. (38°29'25"N, 112°48' 45"W; S side Negro Mag Wash, Mineral Mountains, Adamsville 15' quad., Beaver Co., UT). *Analytical data:* K_2O = 5.10, 5.10%, $^{*40}Ar = 0.058 \times 10^{-10}$ m/g; $^{*40}Ar/\Sigma Ar$ = 25.8%. *Collected by:* P. W. Lipman, P. D. Rowley, J. S. Pallister, U.S. Geological Survey. *Comment:* Alkalic rhyolite from mostly undevitrified obsidian lava flow at Bailey Ridge.
(rhyolite-obsidian) 0.79 + 0.08 m.y.

2. *DKA 3182* K-Ar
Rhyolite of Mineral Mountains. (38°24'40"N, 112°49' 30"W, NW base of South Twin Flat Mountain and E of Pumice Hole Mine, Mineral Mountains, Adamsville 15' quad., Beaver Co., UT). *Analytical data:* K_2O = 4.63, 4.66%; $^{*40}Ar = 0.047 \times 10^{-10}$ m/g; $^{*40}Ar/\Sigma Ar$ = 47.1%. *Collected by:* P. W. Lipman, P. D. Rowley, J. S. Pallister, U.S. Geological Survey. *Comment:* Alkalic rhyolite-obsidian clast within tuff in Ranch Canyon containing sparse phenocrysts and local spherulites (table 1).
(rhyolite-obsidian) 0.70 + 0.04 m.y.

3. *DKA 3184* K-Ar
Rhyolite of Mineral Mountains. (38°24'35"N, 112°49' 05"W; N side of South Twin Flat Mountain, Mineral Mountains, Adamsville 15' quad., Beaver Co., UT). *Analytical data:* K_2O = 8.14, 8.08%; $^{*40}Ar = 0.059 \times 10^{-10}$ m/g; $^{*40}Ar/\Sigma Ar$ = 18.1%. *Collected by:* P. W. Lipman, P. D. Rowley, J. S. Pallister, U.S. Geological Survey. *Comment:* Alkalic rhyolite-obsidian with patchy devitrification and sparse phenocrysts (table 1) from dome at South Twin Flat Mountain.
(sanidine) 0.51 + 0.07 m.y.

4. *DKA 3189* K-Ar
Rhyolite of Mineral Mountains. (38°27'10"N, 112°47' 9"W; W slope at about 2670 m, Bearskin Mountain, Mineral Mountains, Adamsville 15' quad., Beaver, Co., UT). *Analytical data:* K_2O = 4.48, 4.49%; $^{*40}Ar$ = 0.048 x 10^{-10} m/g; $^{*40}Ar/\Sigma Ar$ = 20.2%. *Collected by:* P. W. Lipman, P. D. Rowley, J. S. Pallister, U.S. Geological Survey. *Comment:* Mostly undevitrified alkalic rhyolite-obsidian containing sparse phenocrysts (table 1) from dome at Bearskin Mountain.
(rhyolite-obsidian) 0.75 + 0.10 m.y.

5. *DKA 3315* K-Ar
Rhyolite of Mineral Mountains. (38°27'20"N, 112°47' 30"W; E part of top of Little Bearskin Mountain, Mineral Mountains, Adamsville 15' quad., Beaver Co., UT). *Analytical data:* K_2O = 9.31, 9.15, 9.26%; $^{*40}Ar$ = 0.080 x 10^{-10} m/g; $^{*40}Ar/\Sigma Ar$ = 31.8%. *Collected by:* P. D. Rowley, U.S. Geological Survey. *Comments:* Devitrified alkalic rhyolite-obsidian containing sparse phenocrysts (table 1) from dome at Little Bearskin Mountain.
(sanidine) 0.60 + 0.05 m.y.

6. *DKA 3185* K-Ar
Rhyolite of Mineral Mountains. (38°30'45"N, 112°47' 15"W; 1.9 km ESE of Salt Cove Reservoir, Mineral Mountains, Pinnacle Pass 7½' quad., Beaver Co., UT). *Analytical data:* K_2O = 9.36, 9.35%; $^{*40}Ar = 0.073 \times 10^{-10}$ m/g; $^{*40}Ar/\Sigma Ar$ = 24.5%. *Collected by:* P. W. Lipman, P. D. Rowley, J. S. Pallister, U.S. Geological Survey. *Comments:* Frosty perlite (alkalic rhyolite) with sparse phenocrysts (table 1) from dome 3 km NW of Willow Spring.
(sanidine) 0.54 + 0.06 m.y.

7. *DKA 3188* K-Ar
Rhyolite of White Mountain. (38°54'45"N, 112°29' 45"W; top of White Mountain, 8 km WNW of Meadow Hot Springs, Fillmore 15' quadrangle, Millard Co., UT). *Analytical data:* K_2O = 4.63, 4.70%; $^{*40}Ar$ = 0.029 x 10^{-10} m/g; $^{*40}Ar/\Sigma Ar$ = 15.9%. *Collected by:* P. W. Lipman, P. D. Rowley, J. S. Pallister, U.S. Geological Survey. *Comment:* Undevitrified alkalic rhyolite-obsidian lava flow containing about 6% of hornblende as microphenocrysts (table 1).
(rhyolite-obsidian) 0.43 + 0.07 m.y.

8. *DKA 3186* K-Ar
Rhyolite of Cudahy Mine. (38°45'25"N, 112°50' 50"W; Cudahy Mine, Black Rock Desert, SW part of Cruz SE 7½' quad., Millard Co., UT). *Analytical data:* K_2O = 4.91, 4.93%; $^{*40}Ar$ = 0.168 x 10^{-10} m/g; $^{*40}Ar/\Sigma Ar$ = 46.0%. *Collected by:* P. W. Lipman, P. D. Rowley, J. S. Pallister, U.S. Geological Survey. *Comment:* Lava flows of alkalic rhyolite-obsidian (table 1).
(rhyolite-obsidian) 2.38 + 0.15 m.y.

9. *DKA 3195* K-Ar
Rhyolite of South Twin Peak. (38°44'40"N, 112°46' 40"W; 6 km E of Cudahy Mine, Black Rock Desert, NE part of Antelope Spring 7½' quad., Millard Co., UT). *Analytical data:* K_2O = 11.13, 11.12%; $^{*40}Ar$ = 0.373 x 10^{-10} m/g; $^{*40}Ar/\Sigma Ar$ = 54.3%. *Collected by:* P. W. Lipman, P. D. Rowley, J. S. Pallister, U.S. Geological Survey. *Comment:* Devitrified rock (alkalic rhyolite?) containing sparse phenocrysts (table 1).
(sanidine) 2.33 + 0.12 m.y.

10. *DKA 3314* K-Ar
Rhyolite of Crater Springs. (39°41'30"N, 122°45' 22"W; N edge of the Hogback, Fumarole Butte, the Hogback 7½' quad., Juab Co., UT). *Analytical data:* K_2O = 9.57, 9.38, 9.47%; $^{*40}Ar$ = 0.939 x 10^{-10} m/g; $^{*40}Ar/\Sigma Ar$ = 68.3%. *Collected by:* G. L. Galyardt. *Comment:* Lava flows of alkalic rhyolite composed of rhyolite-obsidian containing sparse phenocrysts (table 1).
(sanidine) 6.87 + 0.28 m.y.

11. *DKA 3192* K-Ar
Rhyolite of Staats Mine. (38°14'45"N, 113°34'45"W; N of Sawmill Canyon, Wah Wah Mountains, the Tetons 7½' quad., Beaver, Co., UT). *Analytical data:* K_2O = 8.86, 8.84%; $^{*40}Ar$ = 2.582 x 10^{-10} m/g; $^{*40}Ar/\Sigma Ar$ = 74.0%. *Collected by:* D. A. Lindsey, U.S. Geological Survey. *Comment:* Devitrified alkalic rhyolite plug(?) containing sparse phenocrysts (table 1).
(sanidine)20.16 + 0.86 m.y.

12. *DKA 3193* K-Ar
Rhyolite of Dead Horse Reservoir. (38°14'25"N, 113° 14'25"W; E of Dead Horse Reservoir, Shauntie Hills, Thermo 15' quad., Beaver Co., UT). *Analytical data:* K_2O = 10.44, 10.37%; $^{*40}Ar$ = 1.756 x 10^{-10} m/g; $^{*40}Ar/\Sigma Ar$ = 87.2%. *Collected by:* P. W. Lipman, P. D. Rowley, J. S. Pallister, U.S. Geological Survey. *Comment:* Devitrified alkalic rhyolite plug containing sparse phenocrysts (table 1).
(sanidine) 11.68 + 0.46 m.y.

13. *DKA 3183* K-Ar
Rhyolite of Thermo Hot Springs. (38°10'30"N, 113°9' 50"W; 3 km E of Thermo Hot Springs, Escalante Desert, Thermo 15' quad., Beaver Co., UT). *Analytical data:* K_2O = 9.11, 9.04%; $^{*40}Ar$ = 1.347 x 10^{-10} m/g; $^{*40}Ar/\Sigma Ar$ = 82.0%. *Collected by:* P. W. Lipman, P. D. Rowley, J. S. Pallister, U.S. Geological Survey. *Comment:* Alkalic rhyolite plug(?) of hydrated glass having patchy devitrification and containing sparse phenocrysts (table 1).
(sanidine) 10.28 + 0.40 m.y.

14. *DKA 3194* K-Ar
Rhyolite of Blue Ribbon Summit. (38°10'10"N, 112° 50'25"W; Blue Ribbon Summit, Black Mountains, Minersville 15' quad., Beaver Co., UT). *Analytical data:* K_2O = 8.96, 8.94%; $^{*40}Ar$ = 0.950 x 10^{-10} m/g; $^{*40}Ar/\Sigma Ar$ = 50.2%. *Collected by:* P. W. Lipman, P. D. Rowley, J. S. Pallister, U.S. Geological Survey. *Comment:* Alkalic rhyolite dome of frothy perlite containing sparse phenocrysts (table 1).
(sanidine) 7.36 + 0.40 m.y.

TABLE 1. Modal data for analyzed samples of young rhyolites in west-central Utah
[At least 2,000 points were counted on thin sections, except for 75L-17, 75L-23, and 75L-19, for which mineral volumes were estimated]

Sample number	Plagioclase	Quartz	K-feldspar	Biotite	Modes (volume percent) Hornblende	Sphene	Clinopyroxene	VRFs	Opaques	Groundmass
75L-17		0.1								99.9
75L-15	0.6	0.4	0.8	Trace	nd	nd	nd	nd	Trace	98.2
75L-16	1.2	2.3	3.9	Trace	nd	nd	nd	nd	Trace	92.6
75L-56	0.3	1.2	1.2	0.1	nd	nd	nd	nd	Trace	97.2
75R-53	0.9	1.0	1.9	nd	nd	nd	nd	0.1	0.1	96.0
75L-18A	0.4	0.7	1.3	0.1	nd	nd	nd	nd	0.1	97.4
75L-23	nd	nd	nd	nd	6	nd	nd	nd	nd	94
75L-19	nd	nd	nd	nd	nd	nd	nd	nd	nd	100
75L-21	5.8	nd	1.2	Trace	nd	nd	1.2	nd	0.6	91.2
7C-75	0.7	7.8	10.0	Trace	0.2	nd	nd	nd	0.1	81.2
ST-R	2.9	1.3	7.8	0.1	nd	nd	nd	nd	0.1	87.8
75L-14A	5.9	7.6	5.7	1.0	nd	0.1	nd	nd	0.5	79.2
75L-13A	0.6	1.8	1.0	nd	0.1	nd	nd	nd	0.1	96.4
75L-12	1.4	3.1	2.6	0.4	nd	nd	nd	nd	0.2	92.3

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