GEOSPATIAL DISTRIBUTION OF TEPHRA FALL IN ALASKA: A GEODATABASE COMPILATION OF PUBLISHED TEPHRA FALL OCCURRENCES FROM THE PLEISTOCENE TO THE PRESENT

Katherine M. Mulliken, Janet R. Schaefer, Cheryl E. Cameron

Miscellaneous Publication 164

$5.00

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March 2018
State of Alaska
Department of Natural Resources
Division of Geological & Geophysical Surveys
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Suggested citation:
http://doi.org/10.14509/29847
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Katherine M. Mulliken¹, Janet R. Schaefer¹, Cheryl E. Cameron¹

ABSTRACT
Tephra fall (volcanic ash) studies are a key component to understanding the frequency and magnitude of volcanic eruptions and conducting volcano-hazard assessments. In addition, many interdisciplinary studies rely on tephra fall deposits as time-stratigraphic markers. Information on tephra deposits in Alaska has previously been dispersed amongst hundreds of publications that span numerous research disciplines. In order to streamline tephra occurrence data, information from these disparate publications have been compiled into one comprehensive geospatial dataset. Pleistocene, Holocene, and historical tephra deposit distribution information has been digitized for more than 120 published resources, including peer-reviewed articles, reports, and theses/dissertations. The dataset includes tephra fall distribution information pertaining to 39 eruptions from at least 19 volcanoes in Alaska.

INTRODUCTION
Tephra fall describes products of an explosive volcanic eruption, which travel through the air before being deposited. These products may range in size and density with larger, denser particles generally falling out near the vent and smaller particles such as volcanic ash (<2 mm) traveling tens to hundreds of kilometers distally. Once deposited, tephra fall can be preserved in the geologic record by burial and/or soil development. The area of deposition depends on the size of the eruption and wind direction and strength at the time of the eruption. Typically, a fall deposit from an explosive eruption will decrease in thickness with distance from the source. Tephra fall deposits are mapped as contours of equal deposit thickness (isopach), equal mass-per-unit area (isomass), or equal maximum grain-size (isopleth).

In Alaska, there are over 100 volcanoes, 54 of which have been active historically (Cameron and Schaefer, 2016), and numerous tephra fall deposits of various ages are found throughout the state. For decades, researchers in fields such as volcanology, paleoenvironmental studies, and archaeology have encountered tephra deposits in Alaska and published data on those occurrences. Tephra fall data reporting is not standardized, thus the amount and types of information recorded vary among publications. Digitally accessible formats, especially geospatial data of tephra occurrences and aerial distribution, are increasingly useful for multidisciplinary studies (e.g., Mastin and others, 2013; Schaefer and Wallace, 2012; Schaefer, 2015; Wallace and others, 2013). Tephra fall occurrence data includes dispersion area, contours describing deposit thickness, maximum particle size, or mass-per-unit area, locations of occurrence and physical descriptions.

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This report provides Alaska tephra fall occurrence data readily accessible in one location and in digital geospatial format.

**DATASET DESCRIPTION AND LIMITATIONS**

This dataset contains an ESRI ArcGIS file geodatabase with established relationship classes (Figures 1 and 2). There are five feature classes, three tables, and five relationship classes. Three feature classes are newly published here (digitized based on previously published information), and two previously published datasets are included as references (Cameron and Schaefer, 2016; Cameron and Nye, 2014). In addition, a layer file symbolizing all digitized data is provided, as well as layer files for each tephra unit with published contours (Table 1 and Figure 3), with pre-defined queries for relevant data. Layer files group relevant data for each tephra unit from multiple feature classes and preserve the path to the source data while retaining the symbology and selection. Included in this publication is a map document with all layer files. As a default, the map document opens with the “Alaska Tephra All” layer displayed, which symbolizes all data in the geodatabase. By using the “List By Drawing Order” option in the map document Table Of Contents, the user can choose to display layers that symbolize deposits of interest. All data are projected using Alaska Albers and the 1983 North American Datum.

- **Feature Classes:**
  - alaska_tephra_contours: polylines representing digitized tephra fall contours;
  - alaska_tephra_footprints: polygons representing maximum tephra fall distribution extents;
  - geodiva_stations_12072017: points that represent tephra sample locations;
  - Previously published reference feature classes:
    - alaska_historically_active_volcanoes: points for locations of the 54 historically active volcanoes in Alaska (Cameron and Schaefer, 2016);
    - alaska_quaternary_volcanic_vents: points for the volcanic vents in Alaska that have been active in the Quaternary Period (Cameron and Nye, 2014).

- **Tables:**
  - table_geodiva_samples_12072017: list of tephra samples and metadata;
  - table_references: list of references for all digitized data;
  - table_alaska_tephra_contours_figures: list of figures with data that was digitized, with figures attached for user reference.

- **Relationship Classes** (associate feature classes or tables to each other):
  - relationship_contours_have_figures;
  - relationship_contours_have_references;
  - relationship_footprints_have_references;
  - relationship_samples_have_references;
  - relationship_stations_have_samples.
Figure 1. Feature classes, relationship classes, and tables in the Alaska tephra geospatial dataset. Feature classes are green, tables are orange, and relationship classes are grey. Data types are noted in brackets. Previously published reference datasets, Alaska historically active volcanoes (Cameron and Schaefer, 2016) and Alaska quaternary vents (Cameron and Nye, 2014), are not included because they are standalone datasets without relationship classes.
Figure 2. Snapshot of the Alaska tephra geospatial dataset. The dataset contains tephra contour lines, tephra footprints, and stations with tephra samples.
Table 1. Layer files available with this publication. Layer files include pre-queried data on deposit contours, maximum distribution footprints, tephra sample locations, and vent locations; one layer file includes all data. The layer files listed here represent only a subset of the data found in the geodatabase.

<table>
<thead>
<tr>
<th>Layer (deposit) Name</th>
<th>Deposit Age</th>
<th>Age Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska Tephra All (all data in database)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Aniakchak 1931 Aniakchak II CFE</td>
<td>1931 CE</td>
<td>Alaska historical</td>
</tr>
<tr>
<td></td>
<td>3430 ± 70 14C yr BP</td>
<td>Bacon and others (2014)</td>
</tr>
<tr>
<td>Augustine 2006</td>
<td>2006 CE</td>
<td>Alaska historical</td>
</tr>
<tr>
<td>Augustine 1976</td>
<td>1976 CE</td>
<td>Alaska historical</td>
</tr>
<tr>
<td>Augustine Tephra B</td>
<td>390 14C yr BP1</td>
<td>Waitt and Begét (2009)</td>
</tr>
<tr>
<td>Augustine Tephra M</td>
<td>750 14C yr BP1</td>
<td>Waitt and Begét (2009)</td>
</tr>
<tr>
<td>Augustine Tephra C</td>
<td>1200–1000 14C yr BP1</td>
<td>Waitt and Begét (2009)</td>
</tr>
<tr>
<td>Augustine Tephra H</td>
<td>1500–1400 14C yr BP1</td>
<td>Waitt and Begét (2009)</td>
</tr>
<tr>
<td>Augustine Tephra I</td>
<td>1700 14C yr BP1</td>
<td>Waitt and Begét (2009)</td>
</tr>
<tr>
<td>Crater Peak, Spurr 1992</td>
<td>1992 CE</td>
<td>Alaska historical</td>
</tr>
<tr>
<td>Crater Peak, Spurr 1953</td>
<td>1953 CE</td>
<td>Alaska historical</td>
</tr>
<tr>
<td>Drum Sheep Creek Tephra-F</td>
<td>190,000 ± 20,000 14C yr BP</td>
<td>Berger and others (1996)</td>
</tr>
<tr>
<td>Edgecumbe Dacite (MED)</td>
<td>11,250 ± 50 14C yr BP</td>
<td>Begét and Motyka (1998)</td>
</tr>
<tr>
<td>Edgecumbe Tephra Set</td>
<td>11,300–12,000 14C yr BP</td>
<td>Riehle and others (1992)</td>
</tr>
<tr>
<td>Emmons Lake Volcanic Center Tephra-C2 CFE</td>
<td>24,000 14C yr BP1</td>
<td>Froese and others (2002)</td>
</tr>
<tr>
<td>Emmons Lake Volcanic Center Old Crow Tephra</td>
<td>124,000 ± 10,000 14C yr BP</td>
<td>Preece and others (2011)</td>
</tr>
<tr>
<td>Fisher Maar</td>
<td>Recent</td>
<td>Stelling (2003)</td>
</tr>
<tr>
<td>Hayes Oshetna Tephra</td>
<td>6000 14C yr BP1 - Oshetna</td>
<td>Child and others (1998); Wallace and others (2014); Mulliken (2016)</td>
</tr>
<tr>
<td>Hayes Tephra Set H</td>
<td>3750 ± 30–3200 ± 30 14C yr BP</td>
<td>Child and others (1998); Wallace and others (2014); Mulliken (2016)</td>
</tr>
<tr>
<td>Kaguyak CFE</td>
<td>5800 14C yr BP1</td>
<td>Fierstein (2007)</td>
</tr>
<tr>
<td>Katmai Lethe Assemblage</td>
<td>12,000–16,000 14C yr BP</td>
<td>Fierstein (2007)</td>
</tr>
<tr>
<td>Mageik Orange Dacite Lapilli</td>
<td>3800–4000 14C yr BP</td>
<td>Fierstein (2007)</td>
</tr>
<tr>
<td>Mageik Lower Grey Ash</td>
<td>3600 14C yr BP1</td>
<td>Fierstein (2007)</td>
</tr>
<tr>
<td>Makushin Driftwood Pumice</td>
<td>5070–7740 14C yr BP</td>
<td>Bean (1999)</td>
</tr>
<tr>
<td>Mt. Churchill White River Ash-North</td>
<td>1900 14C yr BP1</td>
<td>Preece and others (2014); Clague and others (1995)</td>
</tr>
<tr>
<td>Mt. Churchill White River Ash-East</td>
<td>1147 cal yr BP6</td>
<td>N/A</td>
</tr>
<tr>
<td>Mt. Churchill White River Ash-all</td>
<td>North and East deposits</td>
<td>N/A</td>
</tr>
<tr>
<td>Novarupta 1912 CFE</td>
<td>1912 CE</td>
<td>Alaska historical</td>
</tr>
<tr>
<td>Okmok 2008</td>
<td>2008 CE</td>
<td>Alaska historical</td>
</tr>
<tr>
<td>Okmok Middle Scoria</td>
<td>12,000–2050 ± 50 14C yr BP</td>
<td>Alaska historical; Begét and others (2005)</td>
</tr>
<tr>
<td>Pavlof general</td>
<td>General</td>
<td>Alaska historical</td>
</tr>
<tr>
<td>Redoubt 2009</td>
<td>2009 CE</td>
<td>Alaska historical</td>
</tr>
<tr>
<td>Redoubt 1989-1990</td>
<td>1989 CE</td>
<td>Alaska historical</td>
</tr>
<tr>
<td>Redoubt 1966</td>
<td>1966 CE</td>
<td>Alaska historical</td>
</tr>
<tr>
<td>Shishaldin 1999</td>
<td>1999 CE</td>
<td>Alaska historical</td>
</tr>
<tr>
<td>Ukinrek Maars 1977</td>
<td>1977 CE</td>
<td>Alaska historical</td>
</tr>
<tr>
<td>Unknown vent Middle Basic Layer</td>
<td>15,000–12,000 yrs5</td>
<td>Nayudu (1964)</td>
</tr>
<tr>
<td>Unknown vent Lowered Ash Layer</td>
<td>30,000–25,800 ± 1300 14C yr BP</td>
<td>Nayudu (1964)</td>
</tr>
<tr>
<td>Unknown vent Variegated Tephra</td>
<td>106,000 ± 10,000 14C yr BP</td>
<td>Jensen and others (2011)</td>
</tr>
</tbody>
</table>

All ages are Alaska historical or uncalibrated radiocarbon years before present (14C yr BP) unless otherwise noted. Error not reported for deposit age; 1thermoluminescence age; 2glass fission-track age; 3Clague and others (1995) only report the calibrated age range for the Mt. Churchill White River Ash-East deposit; 4Nayudu (1964) bases the age estimate of the Unknown vent Middle Basic Layer on stratigraphy; 5infrared stimulated luminescence age.
Figure 3. Example of pre-queried layer files for five of the 39 tephra units with contours and maximum distributions. Pre-queried layer file displays can be accessed easily in the ArcMap document by selecting the “List by Drawing Order” icon in the Table of Contents, and toggling the layers on or off.
Approximately 700 tephra fall contour lines have been digitized, pertaining to 39 eruptions from at least 19 volcanoes. For each tephra unit with contours or other distributional data, a tephra fall footprint polygon was derived, which describes the approximate maximum interpreted distribution of that unit. In addition, approximately 4,500 tephra samples collected from approximately 1,600 stations were exported from the Alaska Tephra Database module of the Alaska Volcano Observatory’s Geologic Database of Information on Volcanoes in Alaska (GeoDIVA) (Cameron and others, 2015; Cameron and others 2016a; Cameron and others 2016b) on December 7, 2017, and are included in this dataset. For this publication, we have named the feature class (stations) and table (tephra samples) exported from GeoDIVA with a query date, e.g., “geodiva_stations_12072017” indicates the station point features were queried from GeoDIVA on December 7, 2017. The full bibliographic references for all data are contained in the references table.

This dataset is a compilation of data from numerous publications and thus has limitations. The accuracy of tephra deposit contours is dependent on the original publications from which the tephra fall distributional data were digitized. Table 2 presents a list of references with figures that were difficult to digitize and tephra fall unit footprints that were difficult to derive. Geospatial accuracy issues arose when contours and sample locations were digitized from very small, manually georeferenced illustrations and map figures. However, these accuracy issues have been mitigated by using landmark cities, vent locations, major geographic features, geopolitical boundaries, roads, and rivers as a means to quality-control digitization of data from small illustrations and maps.

Occasionally, ashfall contours from the same eruption(s) appear in multiple publications. Where those contours are notably different in shape and size, the contours were digitized from multiple publications. However, in some instances, the ashfall contours from the same eruption(s) were essentially identical between publications and therefore, in order to avoid dataset duplications, only the original reference reporting the ashfall contour was digitized. The additional publications that report duplicate ashfall contours are noted in the “other.refs” field in the “alaska_tephra_contours” polyline feature class.

Individual publications report geochronologic information in different ways, with no uniform standards, resulting in a variety of formats that make it difficult to design query-friendly age data fields. In addition, as eruption histories are refined with more study and improved dating techniques, so are the ages of specific tephra deposits. Therefore, in this report, we present ages from the original reference that the contour was digitized from, as well as a “best age.” Sometimes the original reference is the only age reported and therefore it is also the best age. However, the best age may alternatively be from a more recent publication (i.e., the date reported in the publication with the tephra geospatial information is no longer an accepted age for that deposit/eruption). Ages listed in this dataset are meant to guide researchers, who are encouraged to refer to original publications for more detail on deposit geochronology.
**Table 2.** Summary of digitizing difficulties.

<table>
<thead>
<tr>
<th>Reference(s)</th>
<th>Difficulty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Begét and others (1992); Moodie and others (1995); West and Donaldson (2001); West (2007); Jensen (2007); Lerbebekmo (2008); Dunning (2011); Mullen (2012)</td>
<td>The Mt. Churchill White River Ash-all tephra footprint has a very irregular boundary that is not reflective of the actual deposit, but rather the contours that the deposit footprint was derived from. The irregular boundaries have been smoothed for the individual White River Ash East and North lobe deposit footprints.</td>
</tr>
<tr>
<td>Berger and others (1996)</td>
<td>Berger and others provide a rough approximation of the distribution of the Drum Sheep Creek Tephra-F. The tephra footprint is undefined north of the footprint polygon, which is why the west-east boundaries are sharp (not reflective of the actual deposit).</td>
</tr>
<tr>
<td>Child and others (1998); Davies and others (2016)</td>
<td>The Hayes Oshetna Tephra footprint has a bilobate distribution due to two differing published distributions. It is unknown whether the actual deposit is bilobate.</td>
</tr>
<tr>
<td>Dunning (2011), figure 4.9</td>
<td>There were few landmarks on the figure to aid in georeferencing.</td>
</tr>
<tr>
<td>Fierstein and Hildreth (1992), figures 5, 14, and 16</td>
<td>There were few landmarks on the figure to aid in georeferencing.</td>
</tr>
<tr>
<td>Fierstein (2007)</td>
<td>The Mageik Orange Dacite Lapilli Fall and Mageik Lower Grey Ash tephra footprints have sharp corners that are not actually reflective of the deposits, but rather the contours the deposit footprints were derived from.</td>
</tr>
<tr>
<td>Fierstein (2007) figures 8 and 14</td>
<td>There were few landmarks on the figure to aid in georeferencing.</td>
</tr>
<tr>
<td>Johnston (1978); Kienle and Swanson (1983); Fierstein and Hildreth (2001); de Fontaine (2003); Stevens (2012)</td>
<td>The Augustine 1976 eruption footprint has sharp corners that are not actually reflective of the deposit but represent the intersection of contours the footprint was derived from.</td>
</tr>
<tr>
<td>Larsen and others (2015); Unema and others (2016)</td>
<td>The Okmok 2008 eruption footprint has a very irregular boundary that is not actually reflective of the deposit, but rather the contours the footprint was derived from.</td>
</tr>
<tr>
<td>Nicholson (2003) figures 10, 11, 12, and 13</td>
<td>There were few landmarks on the figure to aid in georeferencing.</td>
</tr>
<tr>
<td>Riehle and others (1998); Fierstein and Hildreth (2008)</td>
<td>The Kaguyak CFE deposit footprint comes to a point along its southern margin; this is not reflective of the actual deposit, but rather the contours the deposit footprint was derived from.</td>
</tr>
<tr>
<td>Stelling (2003); Stelling and others (2005); Gardner and others (2007); Stelling and others (2014)</td>
<td>The Fisher CFE tephra footprint is derived from multiple references with sharp contour boundaries, resulting in an odd tephra footprint polygon with sharp boundaries.</td>
</tr>
<tr>
<td>Waitt and Begét (2009)</td>
<td>The Augustine Tephras B, C, H, I, and M footprints have sharp boundaries not actually reflective of the deposits, due to the tephra contours the footprints were derived from.</td>
</tr>
<tr>
<td>Waythomas and others (2006); Waythomas (2015)</td>
<td>The Pavlof general tephra footprint is not eruption-specific but does provide an estimate for the distribution of general Pavlof tephra.</td>
</tr>
<tr>
<td>Wilcox (1959); Kienle and Swanson (1983); Waythomas and Nye (2002)</td>
<td>The Crater Peak, Spurr 1953 tephra footprint has a very irregular shape that is not reflective of the actual deposit, but rather the tephra contours that the footprint was derived from.</td>
</tr>
<tr>
<td>Wong (2004) figures 9, 10, 11, 13, and 14; Wong and Larsen (2010) figures 5 and 6</td>
<td>There were slight differences in contour placement and contours present on figures between these two references. For digitization, Wong (2004) was preferred, with additional contours digitized from Wong and Larsen (2010) if they were absent from Wong (2004).</td>
</tr>
</tbody>
</table>
Lastly, as new publications are released that contain tephra distribution data, this dataset compilation will become outdated. The GeoDIVA Alaska Tephra Database is continually updated. Therefore, the static station and samples exported from GeoDIVA on December 7, 2017, and incorporated in this database will eventually be non-comprehensive. We intend to update this dataset to incorporate new data as new datasets are published.

METHODS

As part of an extensive literature review undertaken during population of the Alaska Tephra Database, more than 100 publications containing illustrations or maps with information on the occurrence and distribution of tephra in Alaska were identified. From these publications, approximately 225 figures were saved as individual JPEGs, georeferenced, and contours on the figures were digitized. Tephra contours, footprints, and occurrences were digitized as individual polylines, polygons, and point shapefiles, which were compiled into an ESRI ArcGIS file geodatabase. Relevant metadata garnered from the original publications are documented in tables that now reside in the geodatabase and have established relationships with a table that contains the full references. Users of this dataset are encouraged to refer to the original references for additional information on the deposits. A list of the attributes included in each feature class, and their definitions, are described in Tables 3–8.

Tephra contours are associated with the full references they were digitized from in a one-to-one relationship class with the reference table based on the “citationid” field. The geodatabase stores the published figures that contours were digitized from in the “alaska_tephra_contours_figures” table, with which the contours feature class has a one-to-one relationship class. This allows the user to reference the original figure from which a contour was digitized.

From the digitized contours, maximum distribution tephra “footprints” of each applicable unit were derived and saved as polygons (Figure 4). The maximum distribution tephra “footprints” have a many-to-many relationship class with the references table, i.e., a maximum distribution polygon for a tephra deposit can be derived from more than one reference and a reference could have provided information used to derive more than one maximum tephra distribution polygon.

In order to incorporate distinct tephra occurrences in Alaska, sample and station data tables were exported from the Alaska Tephra Database module of GeoDIVA and incorporated into this dataset. The Alaska Tephra Database is a comprehensive repository for Alaska tephra data and includes sample and station information, chemical analyses, age information and eruption data for published tephra samples, as well as previously unpublished tephra samples collected by Alaska Volcano Observatory (AVO) scientists. Only published stations (geodiva_stations_12072017 point feature class) and tephra samples (table_geodiva_samples_12072017) of known location are included in this dataset, and all data were exported on December 7, 2017. Tephra samples and their stations are associated via a one-to-many relationship class based on the “stationid” field, i.e., one station can have many tephra samples. Using the “sampleid” field, samples have a many-to-many
relationship with their references stored in the references table, i.e., one tephra sample can have many references and one reference may contain many tephra samples.

Table 3. alaska_tephra_contours polyline feature class attributes and definitions.

<table>
<thead>
<tr>
<th>Attribute Field [data type]</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>tephraname [Text]</td>
<td>Informal name of the tephra unit.</td>
</tr>
<tr>
<td>sub_unit [Text]</td>
<td>Contour specific to a subset of the tephra unit (e.g., differences within a deposit thought to represent a specific phase of an eruption, a specific day during a historical eruption, or a distinct feature of a deposit thought to represent a change in the eruption). Value is blank if the contour describes the unit as a whole.</td>
</tr>
<tr>
<td>sourcevolc [Text]</td>
<td>If the tephra unit has a known potential source vent.</td>
</tr>
<tr>
<td>isopach_cm [Text]</td>
<td>Contour line denotes isopach (equal deposit thickness), given in cm.</td>
</tr>
<tr>
<td>mass_gm2 [Text]</td>
<td>Contour line denotes isomass (equal mass-per-unit-area of tephra fall), in grams per square meter.</td>
</tr>
<tr>
<td>pleth_cm [Text]</td>
<td>Contour line denotes isopleth (equal maximum grain size, pumice size, or lithic size deposition), given in cm (if given, particle type is noted in the map_info field).</td>
</tr>
<tr>
<td>map_info [Text]</td>
<td>If the digitized map or illustration contained additional useful metadata, it is detailed here.</td>
</tr>
<tr>
<td>comments [Text]</td>
<td>Comments by the digitizer.</td>
</tr>
<tr>
<td>citation [Text]</td>
<td>Citation for the reference that the contour was digitized from.</td>
</tr>
<tr>
<td>age_epoch [Text]</td>
<td>Age epoch of the deposit/eruption (Pleistocene, Holocene, Alaska historical).</td>
</tr>
<tr>
<td>age_in_ref [Text]</td>
<td>Age of deposit/eruption as reported in the reference that the contour is digitized from.</td>
</tr>
<tr>
<td>best_age [Text]</td>
<td>This value may be a deposit age estimate provided in a more recent reference or may be the same as the age estimate provided in the reference that the contour was digitized from.</td>
</tr>
<tr>
<td>age_cit [Text]</td>
<td>Citation for the reference of the age reported in the best_age field.</td>
</tr>
<tr>
<td>age_notes [Text]</td>
<td>Comments on the age determination of the tephra deposit.</td>
</tr>
<tr>
<td>fig_num [Text]</td>
<td>Figure number that the contour was digitized from, in the original reference.</td>
</tr>
<tr>
<td>fig_scale [Text]</td>
<td>Scale of the figure that the contour was digitized from, in the original reference.</td>
</tr>
<tr>
<td>other_cits [Text]</td>
<td>A list of citations for other references that the contour has appeared in.</td>
</tr>
<tr>
<td>citationid [Double]</td>
<td>Unique numeric identifier that allows the contour to be linked with the reference it was digitized from.</td>
</tr>
</tbody>
</table>
Table 4. alaska_tephra_footprints polygon feature class attributes and definitions.

<table>
<thead>
<tr>
<th>Attribute Field [data type]</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>tephname [Text]</td>
<td>Informal name of the tephra unit.</td>
</tr>
<tr>
<td>sourcevolc [Text]</td>
<td>If the tephra unit has a potential source vent.</td>
</tr>
<tr>
<td>citations [Text]</td>
<td>A list of citations for the references that the footprint was derived from.</td>
</tr>
<tr>
<td>age_epoch [Text]</td>
<td>Age epoch of the deposit/eruption (Pleistocene, Holocene, Alaska historical).</td>
</tr>
<tr>
<td>best_age [Text]</td>
<td>This value may be a deposit age estimate provided in a more recent reference or may be the same as the age estimate provided in the reference that the contour was digitized from.</td>
</tr>
<tr>
<td>age_cit [Text]</td>
<td>Citation for the reference of the age reported in the best_age field.</td>
</tr>
<tr>
<td>age_notes [Text]</td>
<td>Comments on the age determination of the tephra deposit.</td>
</tr>
<tr>
<td>prox_desc [Text]</td>
<td>If available, a proximal description of the deposit.</td>
</tr>
<tr>
<td>prox_cit [Text]</td>
<td>Citation for the reference of the proximal deposit description.</td>
</tr>
<tr>
<td>dist_desc [Text]</td>
<td>If available, a distal description of the deposit.</td>
</tr>
<tr>
<td>dist_cit [Text]</td>
<td>Citation for the reference of the distal deposit description.</td>
</tr>
<tr>
<td>comments [Text]</td>
<td>Comments by the digitizer.</td>
</tr>
<tr>
<td>footprintid [Double]</td>
<td>Unique numeric identifier that allows the footprint to be linked with the references that it was derived from.</td>
</tr>
<tr>
<td>SHAPE_AREA [Double]</td>
<td>ArcGIS-generated shape area (in square meters).</td>
</tr>
</tbody>
</table>

Table 5. geodiva_stations_12072017 point feature class attributes and definitions.

<table>
<thead>
<tr>
<th>Attribute Field [data type]</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>stationid [Text]</td>
<td>The alphanumeric descriptor of the sample's station. For samples published without a station identifier, we use the sample's id as a station id. For stations with generic names (1, 2, 3, a, b, c, etc.), we assign the station with the nomenclature: first author last name_publication year_station number.</td>
</tr>
<tr>
<td>lat_nad83 [Double]</td>
<td>Latitude of sample location, if known (NAD83 datum). Sometimes, these coordinates are imprecise because they were georeferenced from a figure or approximated based on a location description. If so, it is noted in the description.</td>
</tr>
<tr>
<td>long_nad83 [Double]</td>
<td>Longitude of sample location, if known (NAD83 datum). Sometimes, these coordinates are imprecise because they were georeferenced from a figure or approximated based on a location description. If so, it is noted in the description.</td>
</tr>
<tr>
<td>geologist [Text]</td>
<td>Name of the geologist who visited the station and collected the sample, if known.</td>
</tr>
<tr>
<td>volcano [Text]</td>
<td>If the station that was visited was on a volcano, the volcano name is specified here.</td>
</tr>
<tr>
<td>visitdate [Text]</td>
<td>Date the sample was collected. Sometimes only the year is known.</td>
</tr>
<tr>
<td>stationdes [Text]</td>
<td>Text description of the sample locality, if published. If no sample location was published, a specific volcano name or geographic area may be entered.</td>
</tr>
<tr>
<td>stationcom [Text]</td>
<td>Comments about the station.</td>
</tr>
</tbody>
</table>
Table 6. table_geodiva_samples_12072017 attributes and definitions.

<table>
<thead>
<tr>
<th>Attribute Field [data type]</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sampleid [Text]</td>
<td>Alphanumeric descriptor of the sample. For samples with generic names (1, 2, 3, a, b, c, etc.), we assign the sample name with the nomenclature: first author last name_publication year_sample number.</td>
</tr>
<tr>
<td>stationid [Text]</td>
<td>The alphanumeric descriptor of the sample's station. For samples published without a station identifier, we use the sample's id as a station id. For stations with generic names (1, 2, 3, a, b, c, etc.), we assign the station with the nomenclature: first author last name_publication year_station number.</td>
</tr>
<tr>
<td>at_num [Text]</td>
<td>Alphanumeric ID assigned by the Alaska Tephra Lab.</td>
</tr>
<tr>
<td>sourcevolc [Text]</td>
<td>If the tephra unit has a potential source vent.</td>
</tr>
<tr>
<td>samp_date [Text]</td>
<td>Date the sample was collected. Sometimes only the year is known.</td>
</tr>
<tr>
<td>samptype [Text]</td>
<td>samptype and sampletype2 describe the physical sample type.</td>
</tr>
<tr>
<td>samptype2 [Text]</td>
<td>samptype and sampletype2 describe the physical sample type.</td>
</tr>
<tr>
<td>age_epoch [Text]</td>
<td>Age epoch of the deposit/eruption (Pleistocene, Holocene, Alaska historical).</td>
</tr>
<tr>
<td>color [Text]</td>
<td>Color of the sample, if provided.</td>
</tr>
<tr>
<td>tephraname [Text]</td>
<td>Informal name of the tephra unit.</td>
</tr>
<tr>
<td>alt_tephra [Text]</td>
<td>Some tephra units have been given multiple names, this field provides an alternate tephra name for those samples with multiple tephra unit names.</td>
</tr>
<tr>
<td>name_comm [Text]</td>
<td>Comments on the tephra unit name.</td>
</tr>
<tr>
<td>sampdes [Text]</td>
<td>Text description of the sample, if published.</td>
</tr>
<tr>
<td>sampcom [Text]</td>
<td>Comments about the sample.</td>
</tr>
</tbody>
</table>

Table 7. table_references attributes and definitions.

<table>
<thead>
<tr>
<th>Attribute Field [data type]</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>citationid [Double]</td>
<td>Unique numeric identifier that allows the reference to be linked to derived data.</td>
</tr>
</tbody>
</table>

Table 8. table_alaska_tephra_contours_figures attributes and definitions.

<table>
<thead>
<tr>
<th>Attribute Field [data type]</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTENT_TYPE [Text]</td>
<td>Describes the attachment type (image/jpeg for all).</td>
</tr>
<tr>
<td>ATT_NAME [Text]</td>
<td>Name of the file that is attached.</td>
</tr>
<tr>
<td>DATA_SIZE [Long Integer]</td>
<td>Size of the attachment.</td>
</tr>
<tr>
<td>DATA [Blob]</td>
<td>Data type.</td>
</tr>
</tbody>
</table>
Figure 4. Redoubt 1989 tephra footprint polygon (lower) derived from digitized tephra contours (upper), from Scott and McGimsey (1994).
Lastly, queried layer files for each tephra unit with a published distribution are also published here. Figure 3 presents examples of five such layer files, which exist for all 39 tephra units in the dataset (there are technically 40 distributions because an overall White River Ash distribution, including both the north and east lobes, is also included as the two deposits are often not distinguished in publications). Separate layer files exist for the Edgecumbe tephra set and Edgecumbe dacite tephra, although the Edgecumbe dacite tephra is considered a member of the tephra set (Begét and Motyka, 1998). For each tephra unit, the layer file contains queried data for the source volcano (if known), the individual contours pertaining to the deposit (if any), the derived maximum tephra distribution for the deposit, and stations with tephra samples of the deposit (if any). Contours are symbolized based on the reference that the contour was digitized from. To access an image of the original figure the contours were derived from, use the ArcMap “HTML Popup” tool to select the feature of interest in the map window. The volcanic vent locations are queried from either the historically active volcanoes (Cameron and Schaefer, 2016) or quaternary volcanic vents (Cameron and Nye, 2014) datasets depending on the vent.

**USING THE DATASET AND FUTURE GOALS**

We would eventually like to integrate this geospatial data with the Tephra Database module of the Alaska Volcano Observatory’s Geologic Database of Information on Volcanoes in Alaska (GeoDIVA) and provide an online interface that will allow users to download specific tephra fall distribution data. Such a feature would aid researchers working at specific locations in Alaska by providing a rough prediction of ashfall units that may be encountered, and their approximate ages. In order to facilitate rapid release of the data, however, we are first publishing this geodatabase, which contains all of the data that is currently digitized.

A map document provides easy access to the queried layer files, which allows users to view data for specific tephra units listed in Table 1. As a base layer, the map document utilizes the Alaska Geospatial Council best data layer web mapping service (available at [http://gis.dnr.alaska.gov/terrapixel/cubeserv/OIM_BDL](http://gis.dnr.alaska.gov/terrapixel/cubeserv/OIM_BDL)). The map document displays the “Alaska Tephra All” layer as a default, but by using the “List By Drawing Order” option of the Table Of Contents, users may select layers to display data relevant to specific deposits of interest. Users may access all data through the “Alaska Tephra All” layer in the map file or by accessing the individual feature classes and tables in the geodatabase. In ArcMap, the “Identify” and “HTML Popup” tools are useful for viewing metadata associated with individual features. We acknowledge that some users may wish to export subsets of data (e.g., only data on certain tephra units) from the geodatabase. Therefore, attribute field names have been limited to ten characters or less (except for Arc-generated geodatabase and attachment fields) to accommodate exporting shapefiles from the geodatabase. Note that features of the geodatabase, such as relationship classes, are not preserved when data are exported from the geodatabase as shapefiles. For example, the “alaska_tephra_contours” feature class has a relationship with a table that stores attachments of published figures with data that was digitized. When shapefiles are exported from the
“alaska_tephra_contours” feature class, the relationship classes it has are not preserved and therefore the attachments of digitized figures will no longer be accessible to users. Likewise, relationship classes linking feature classes and tables to the reference table are not preserved. In addition to the reference table stored in the geodatabase, Appendix 1 contains a full list of references for all data cited in the geodatabase.

ACKNOWLEDGEMENTS

As a compilation of previously published data, this project is built on a foundation of work done by other scientists. The list of authors whose work contributed to this database would be too extensive to cite here, but each is credited in the reference table of the dataset. We would like to thank Patricia Gallagher (DGGS), Mike Hendricks (DGGS), and Kristi Wallace (USGS-AVO) for their review of this publication.

This project was funded through DGGS cooperative agreements with the USGS Volcano Hazards Program, grant numbers G16AC00054 and G16AC00165. The Alaska Volcano Observatory is a joint program of the U.S. Geological Survey, the Geophysical Institute of the University of Alaska Fairbanks, and the State of Alaska Division of Geological & Geophysical Surveys.
REFERENCES CITED

This is a list of references cited in this text document. See “Database References” list at the end of this document or reference tables in dataset for list of compiled data references.


APPENDIX 1: DATABASE REFERENCES CITED

This is a comprehensive list of all sources of compiled data included in the geodatabase.


Swanson, S.E., Nye, C.J., Miller, T.P., and Avery, V.F., 1994, Geochemistry of the 1989-1990 eruption of Redoubt Volcano: Part II, Evidence from mineral and glass chemistry, in Miller,


