TEPHRA OCCURRENCE IN ALASKA: A MAP-BASED COMPILATION OF STRATIGRAPHIC TEPHRA DATA

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TEPHRA OCCURRENCE IN ALASKA: A MAP-BASED COMPILATION OF STRATIGRAPHIC TEPHRA DATA

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ABSTRACT

The principal hazard associated with future explosive eruptions of Alaska volcanoes is the generation of volcanic ash clouds which are explosively blasted high into the atmosphere and then drift away from the volcano with the wind. The fragments in the ash cloud (tephra) vary in size and the heavier particles fall near the source while finer particles travel downwind. This transported tephra will fall out of the cloud and accumulate on surfaces and structures, contaminate water sources, and infiltrate electronics and motors. The weight of significant accumulations may collapse structures and cause other damage. Chronic exposure to ash may be a significant public health hazard. This publication presents the frequency and location of tephra fall throughout Alaska and into the Yukon Territory of Canada, resulting from eruptions of Alaska volcanoes from the Pleistocene to the present.

The tephra occurrence map facilitates better visualization of areas in Alaska with past occurrences of ashfall. The map is a useful indicator of regional potential ashfall hazards.

INTRODUCTION

Hazards from airborne ash and ashfall can impact communities near volcanoes as well as those tens to hundreds of miles away. Records of past eruptions and ashfall occurrences can aid in the preparation and mitigation of hazards associated with future eruptions. The tephra occurrence map is an informative tool used for visualization of tephra records in Alaska. It is the summation of literature and field data review for tephra dispersion information covering the State of Alaska and parts of the Yukon Territory of Canada.

This map synthesizes over 1200 stratigraphic columns located throughout Alaska and the Yukon Territory of Canada (Figure 1). The stratigraphic data is represented as points, conserving information about the deposits at each location. In addition to the stratigraphic station metadata, information about the geographic extent of ashfall events is also included, as well as a grid map which represents the spatial extent and frequency of ashfall over the state. This data is intended for use and visualization in ArcGIS.

This document explains how tephra data was obtained, the interpretation and calculations applied to the data and provides a guide on utilizing the tephra occurrence map.

In this document, the terms *tephra* and *ash* may be used interchangeably.

Tephra: Any type of rock fragment that is forcibly ejected from the volcano during an eruption.

Ash: Fine fragments (less than 2 millimeters across) of lava or rock formed in an explosive volcanic eruption.

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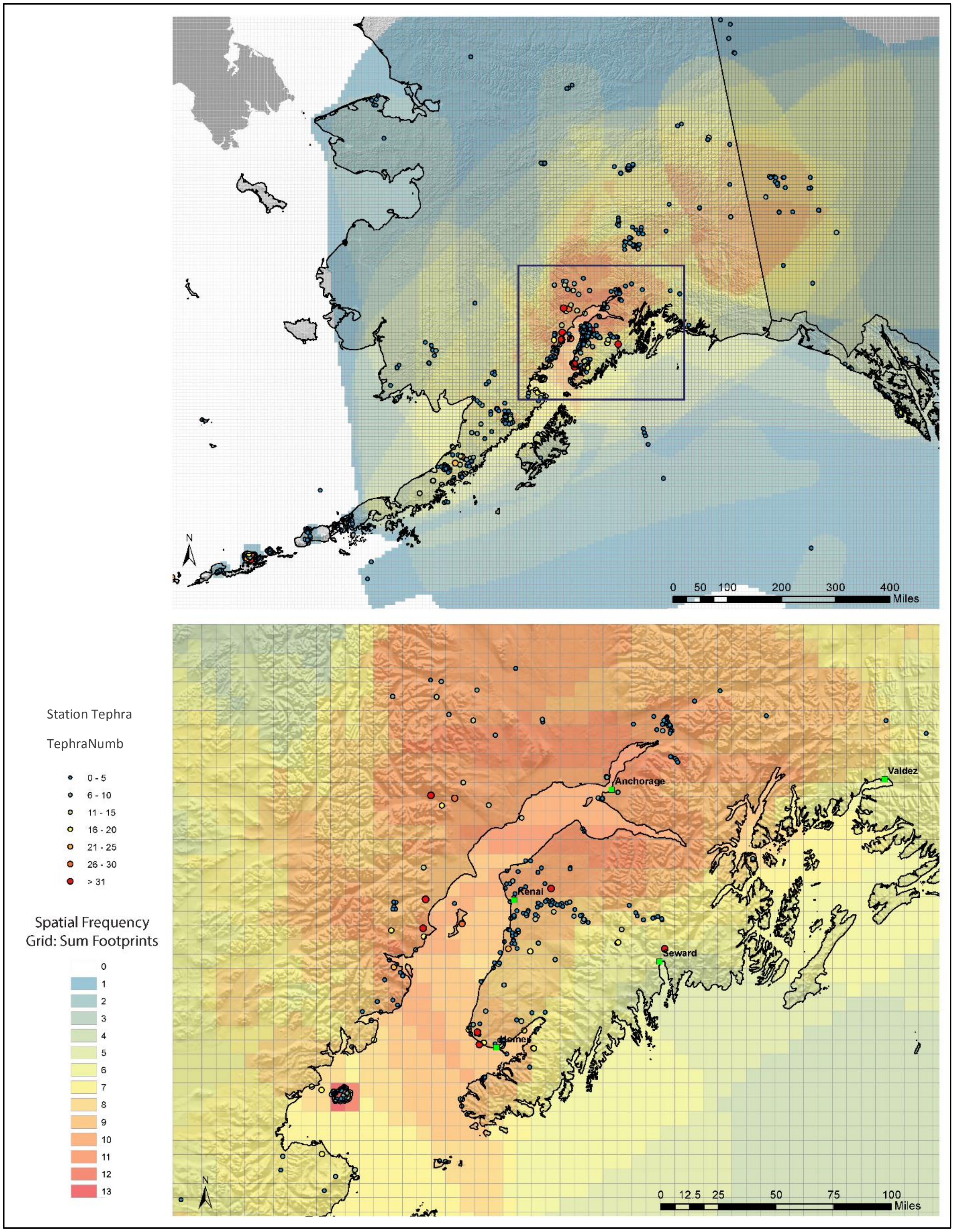

Figure 1: Tephra occurrence information compiled from investigations of geologic deposits throughout Alaska. Inset map (lower panel) highlights the Cook Inlet region. Colored dots represent the number of discrete tephra layers seen at each location. Colored grid indicates the number of tephra footprints recorded for the area.

TEPHRA OCCURRENCE DATABASE

Database Overview

An Excel spreadsheet provides all tabular data used to populate the Stations point layer in the Tephra Occurrence Geospatial Database and derivative map product. The information contained in the spreadsheet is summarized in Table 1 and includes the location of the station, information about the publication that data were derived from, a count of tephra occurrence at each station, as well as any age data and subsequent calculations of recurrence intervals.

Stratigraphic Station Information

The stations dataset within the geodatabase presents the synthesis of over 1200 stratigraphic columns located throughout Alaska and parts of the Yukon Territory of Canada, originally published in 140 references. Unpublished tephra count data by Alaska Volcano Observatory (AVO) staff is also included for the Dutch Harbor/Unalaska region (Makushin volcano, J. Schaefer, written commun.) and the Lower Cook Inlet region (K. Wallace and K. Mulliken, written commun.). Although some stations and basic information were queried from the Alaska Volcano Observatory's (AVO) Geologic Database of Information on Volcanoes in Alaska (GeoDIVA) (Cameron, 2004), an additional 604 stations were added from original references. Primary source documents were also used to compile stratigraphic information not already present in GeoDIVA, including tephra count, stratigraphic section age information, and age calculations, and this new compilation has been entered into the larger GeoDIVA database.

TephraNumb is the total number of discrete ash fall layers reported per station. For stations proximal to a volcanic vent, a single "tephra" may include multiple layers of products erupted during a single eruptive event. These proximal deposit packages are counted as single tephra events. For more distal deposits, layers tend to be thinner and separated by non-volcanic units such as soil, sands, peat, and clay. Stations without tephra layers are not included in this publication but are available upon request (geodiva@avo.alaska.edu).

Age Data

Tephra relative or direct ages and age dating methods were compiled for publications that included age data and presented on a per-station basis.

Dating Methods Used

Calibrated Radiocarbon: calibrated radiocarbon ages reported as calendar ages. These ages were either reported in the publication as calibrated or were calibrated during the creation of this report using Oxcal 4.3 (online version) with the InCal13 terrestrial calibration curve. (Ramsey, 2009; Reimer and others, 2013).

Uncalibrated radiocarbon: radiocarbon ages from publications that gave an uncalibrated age without the necessary metadata needed to produce a calibrated radiocarbon age.

Correlation: an age is reported with a correlation method when a tephra was chemically or visually correlated to a tephra of known age. For tephras resulting from a historically observed eruption, the date of the eruption (year C.E.) is given and the age is marked as an observed eruption.

Less common dating methods in this compilation include: Age Models, K-Ar and $^{40}Ar/^{39}Ar$, Thermoluminescence, Amino Acid Geochronology, Infrared Stimulated Luminescence, Zircon Dating, Teledyne Isotope Analysis, and Glass Fission-Track Dating. See individual publications (Appendix 1) for more information on dating methodologies.

Recurrence Interval and Frequency Calculations

For each station with reported age information, an average minimum recurrence interval was calculated. The recurrence interval represents the average number of years elapsed between tephra depositions. For example, a station at Andrew Lake contained 18 tephra layers and a maximum oldest tephra age of 7500 years before present (yr BP). This information provides a tephra recurrence interval of 417 years. That is, approximately every 417 years it can be expected that 1 tephra will fall in that area (Krawiec, and others, 2013). This recurrence interval is both an approximation and a minimum value, as we only have a minimum count for the possible number of tephras that have fallen and subsequently been preserved in an area and the oldest age data is often not directly correlated to the lowest tephra layer (instead being attributed to layers found below the tephra). Smaller ash fall events can occur without preservation in the geologic record.

Similarly, a tephra frequency was calculated and reports the number of tephra layers per 1000 years. This calculation uses the same information as described above and serves as an alternate method of displaying the expected frequency of tephra producing eruptions.

Table 1. Overview of data included in full tephra occurrence database.

Column/Field Heading	Description
CitationID	Citation ID assigned to the publication in the AVO reference database, GeoDIVA.
Author	The author of the publication used for the data. This is not necessarily the geologist who visited the section.
StationID	Unique ID number assigned to the station for reference in AVO's GeoDIVA database.
Lat_nad83	Latitude of station in decimal degrees, NAD 83 datum.
Long_nad83	Longitude of the station in decimal degrees, NAD 83 datum.
Location	Information on how the location of the station was obtained. If the station was queried from GeoDIVA, coordinates are as found in GeoDIVA. If the station did not previously exist in GeoDIVA, the location is either from specific coordinates given in the text or derived by georeferencing a location map included in the publication.

Column/Field Heading	Description
Station	Station name as represented in GeoDIVA or in the preliminary publication.
TephraNumb	Number of discrete tephra deposits within a stratigraphic section. In some cases with very high tephra counts (and often very thin tephras), the number of discrete tephras was obtained from the text of the publication. This is considered a minimum number of events, as erosion and other natural processes can sometimes destroy deposited tephra layers.
Thickness	Denotes (yes or no) whether stratigraphic thickness information was included in the source publication (not necessarily corresponding to a tephra layer). No numerical thickness data has been compiled at this time.
LowerAge	This field contains the initial ages taken directly from the publication. These ages may be calibrated (if so, the age remains the same when moved to the appropriate field). Information from this column is parsed into the appropriate age column in the spreadsheet. Numbers in parentheses refer to a calendar year. Numbers not in parentheses are yr BP. If the value is null, it indicates that there is no reported tephra at the station. If the value is “unspecified”, it indicates that there is tephra recorded at the station, but no age data.
OldestDate	If the oldest tephra in the sequence is the result of a specific historic eruption, the date of that event is entered here. These dates are entered in years C.E.
OldestAge	Reported ages for the oldest (lowest) tephra in the section, in yr BP.
AgeYrBPmax	For ages with an error margin, this field is the maximum (oldest) age for the lowest tephra.
AgeYrBPmin	For ages with an error margin, this field is the minimum (youngest) age for the lowest tephra.
Confidence	Some calibrations report a percentage confidence interval, typically 1-2 sigma.
MedLowAge	For radiocarbon ages that were calibrated as part of this work, the calculated median age of the oldest/lowest tephra is presented here in yr BP.
Method	Indicates dating method for reported oldest ages. * indicates ages calibrated for this study.
Recurrence	The minimum recurrence interval indicates the average number of years between tephra fall events (yrs/1 tephra). This is calculated by dividing the oldest age of tephra by the number of tephras in the section. This is a minimum recurrence interval because the number of tephra layers in a section is considered a minimum number of events.
FreqTephra	The frequency of tephra occurrence, calculated by dividing the number of tephra layers by the maximum tephra age. This is reported in tephra/1000 years. This field is based on ages provided in publication.

Column/Field Heading	Description
AgeComment	Additional information about the ages of samples, including dating techniques, calibration details, tephra identification, source eruptions, and chronologic sequences.
GenComment	General comments about the station or specific layers within a stratigraphic column. Some age or identifying information may also be included here.
Reference	Reference for the publication containing original station, sample and age data.

INTERACTIVE TEPHRA OCCURRENCE MAP

The tephra occurrence map is in ArcGIS format and contains the collected data for individual stations, tephra distribution, and geographical and population information for Alaska and the Yukon Territory. Data layers included in the map are described in Table 2.

Stations

The map shows the point locations of all stratigraphic sections with reported tephra. The attributes of the Stations feature class mirror the field information provided in Table 1 (this document). Station icons depict tephra count with both size and color gradation – larger symbols in warmer colors indicate higher tephra count values at a station.

Spatial Frequency Grid

Mulliken and others (2018) published a digital compilation of tephra occurrence and dispersion data for the State of Alaska. The Mulliken and others (2018) publication contains tephra "footprint" polygons for those eruptions with published distribution data. These footprints represent a maximum spatial distribution for each eruption. To assist in gauging tephra fall frequency for areas without stratigraphic sections, we used Mulliken and others (2018) publication to derive a spatial tephra frequency grid for the State of Alaska, showing the number of ash footprint polygons overlaying 10 km by 10 km grid squares. The Spatial Frequency Grid polygon feature class contains identifying grid numbers and values for the sum of the footprints (Sum Footprints: reports the number of overlapping tephra footprints that fall within that grid square). This derived grid product contains only tephra-fall deposits and eruptions with existing published information on distribution and is, therefore, a minimum estimate of past tephra fall occurrence.

Table 2. Map elements included in GIS product.

Layer	Description	Default On/Off	Data Source (date obtained)
AK Coast	Alaska coastline in NAD 83 datum	On	http://www.asgdc.state.ak.us/#56 (2018)
Populated Places	Point feature class of cities, towns, and other populated places in Alaska.	Off	http://www.asgdc.state.ak.us/#14 (2018)

Layer	Description	Default On/Off	Data Source (date obtained)
Stations	Point feature class of location and tephra information for stratigraphic sections. Data included in this layer are summarized in Table 1.	On	This report
Spatial Frequency Grid	Gridded polygon feature class containing information about the number of tephras overlapping within each 10x10 km grid square. Reports *Sum Footprints* for each grid square.	On	Derived from Mulliken and others (2018)
DEM NAD83 300m	NAD 83 datum Digital Elevation Model (DEM). Digital image used in USGS Map I-2585 derived from digital elevation model 300m mosaic for Alaska.	On	https://agdc.usgs.gov/data/usgs/erosafo/300m/300m.html (2018)
Alaska Tephra Footprints	Polygons representing the maximum spatial distribution of tephra for each eruption. Note that this is only available for those deposits with existing published information on distribution.	Off	Mulliken and others (2018)

HOW TO USE THIS MAP PRODUCT:

To get data for a specific station or grid square

Use the HTML pop-up tool within ArcGIS to see information for a location in map view (Figure 2). When this tool is selected, the user can click on a station or grid square to pull up information. Multiple popup windows can be opened simultaneously in order to compare values.

A feature class containing the location of cities, towns, and other populated places in Alaska is included in the download package (Populated Places). This is useful in identifying populated areas where information on tephra fall hazards may be in higher demand.

FUTURE GOALS AND DATABASE ADDITIONS:

The current version of this map-based compilation of tephra occurrence in Alaska will serve as a template for Alaska Volcano Observatory (AVO) geologists to record tephra occurrence data for active tephra studies in Alaska. We expect the database to expand as more tephra data become available either by publication or by AVO tephra fieldwork. Tephra occurrence data is now stored in GeoDIVA and a new version of the tephra occurrence map and geodatabase will be released when additional data warrants it.

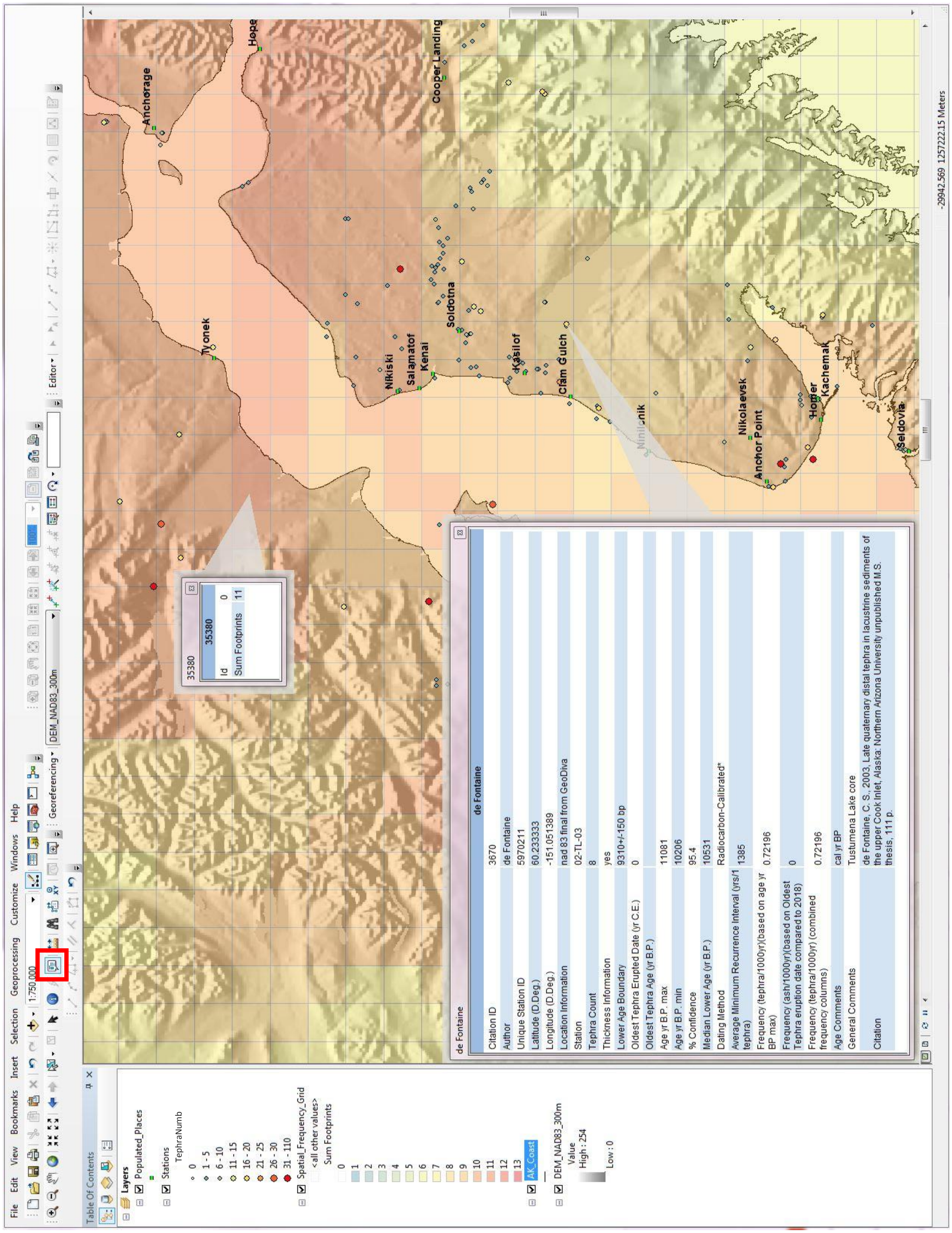

Figure 2. Location of the HTML popup tool (red box) and an example of data display for stations and grid squares.

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