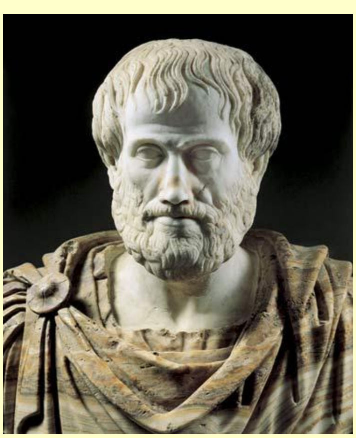
ENEGeol 2017 - PART 1

INTRODUCTION TO TEPHROCHRONOLOGY

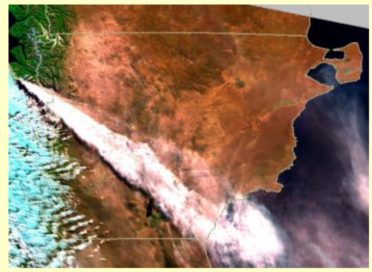

Eruption of Chaiten, 2008

Tephra is an all-embracing term for the explosively erupted, loose fragmental (pyroclastic) products of a volcanic eruption, & includes all grain sizes ranging from the finest dust to blocks the size of cars.

Tephra may include fall deposits (commonly called tephra-fall or tephra fallout) and unconsolidated deposits derived from pyroclastic flows or surges.



The first known written use of 'tephra' was by Aristotle who described an eruption on the island of Hiera in the Lipari (Aeolian) Islands near Sicily around 350 BC.



Tephra deposits have two special features:

(1) they are erupted and deposited over very short time periods, geologically speaking, usually a matter of only hours or days to perhaps weeks or months; and

(2) they can be spread widely over land and sea to form a thin blanket that (unless reworked) has the same age wherever it occurs.

Tephrochronology use of tephra deposits as isochrons to link sequences in different settings via precise tie-points & to establish and transfer relative or numerical ages

Tephrostratigraphy is another term that is commonly used and refers to the study of sequences of tephra layers and related deposits and their relative ages.

It involves defining, describing, and characterizing or 'fingerprinting' tephras or tephra sequences using their physical, mineralogical, or geochemical properties, and fundamentally underpins tephrochronology.

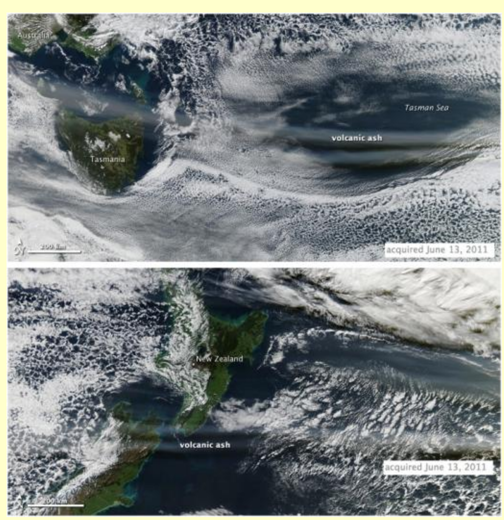
Road cutting near Rotorua showing tephra layers and associated buried paleosols (dark brownish to yellowish-brown horizons) dating back *c.* 18,000 calendar years. Deposition of each tephra was followed by a period of quiescence and soil formation; then the soil was buried by tephra from a new eruption.

Early Studies: Pioneers of Tephrochronology

Sigurdur Thorarinsson
(Iceland) in the field

Colin Vucetich (NZ) in his element alongside tephra beds & buried soil horizons in central North Island during a field trip in February, 1981.

Characteristics of Tephra
Magnitude and Dispersal



2011 eruption of Puyuhue-Cordon Caulle, southern Chile

Three dominant threshold settling velocity values affect the distribution and sorting of airborne tephra:

(1)fragments with large settling velocities follow ballistic trajectories that are little affected by wind;

(2) particles suspended by turbulence in the eruption cloud that are too heavy to be suspended by atmospheric winds;

(3) those light enough to be suspended by wind independently of the eruption cloud.

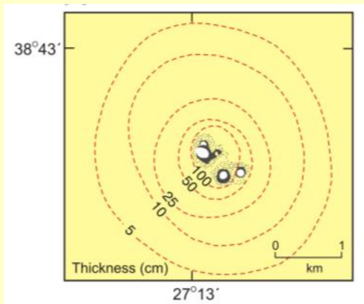
Fire-fountaining at Eyjafjöll volcano, Iceland - March, 2010.

Tephra plume of the 1996 eruption of Ruapehu volcano

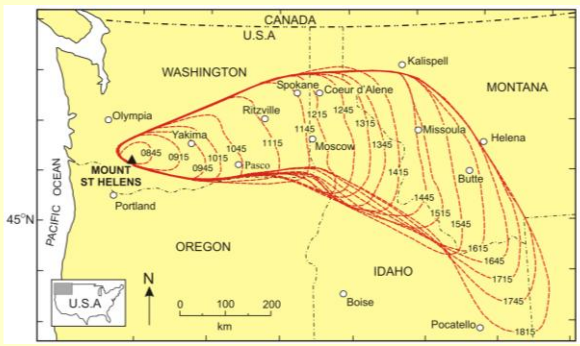
Ash (< 2 mm)

Lapilli (2-64 mm)

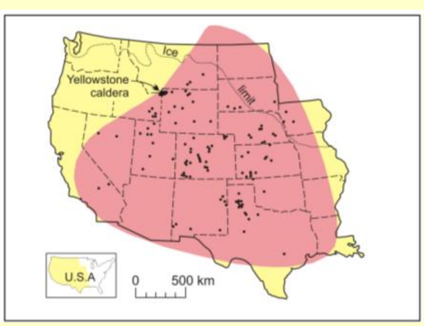
Blocks (dense, angular) & bombs (vesicular, rounded) (>64 mm)

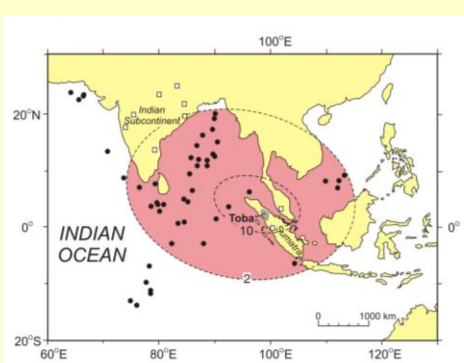


Circular isopach map of Algar do Carrao I scoria-fall deposit associated with a low intensity basaltic eruption at Tereira, Azores



Elliptical pattern associated with the Mt. St. Helens eruption, 1980, that spread as far as a 1000 km from the volcanic centre in less than 10 hours

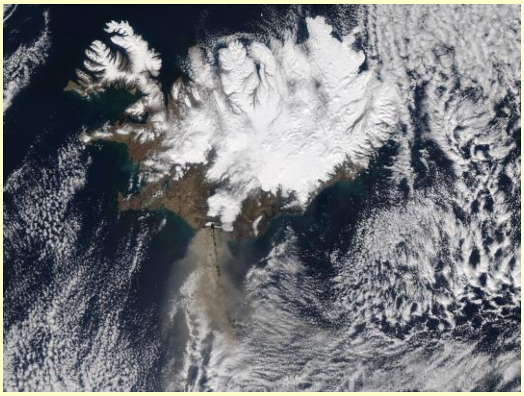


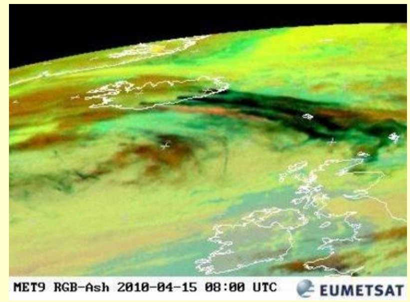


Distributions of two exceptionally large Pleistocene eruptions:

Lava Creek B (ca. 0.64 Ma) from Yellowstone Caldera, west-central USA.

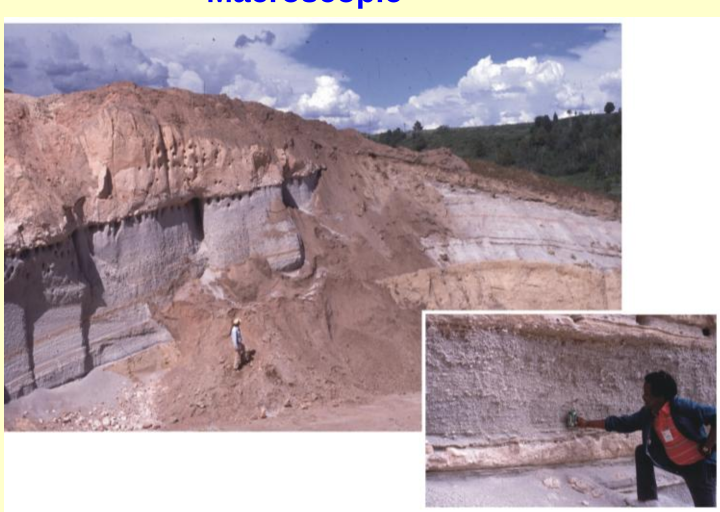
Youngest Toba Tephra (ca. 74 kyr BP) erupted from Toba Caldera Complex in northern Sumatra. Isopach values for Toba Tephra are in centimeters.



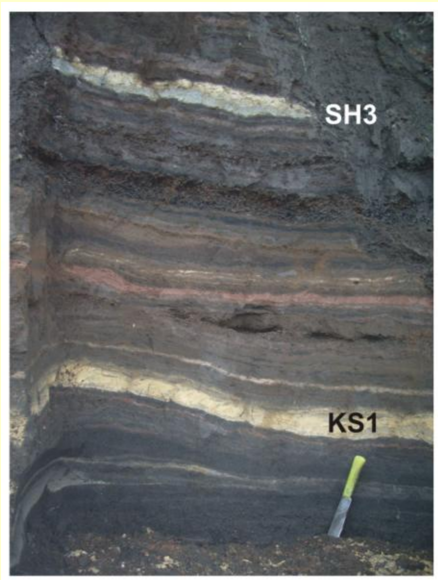


The initial eruption of the Icelandic Eyjafjöll volcano during the Northern Hemispheric spring of 2010 has shown that it is not the most voluminous of eruptions that necessarily result in the widest dispersal of tephra.

Field Characteristics
Macroscopic



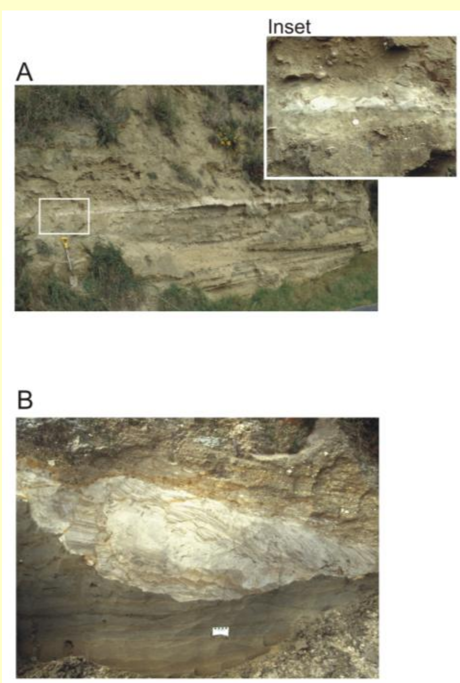
Mesa Falls Tephra sourced from Yellowstone Caldera, U.S.A. mantling pre-existing topography. Inset – gradational coarse-fine internal structure of fall deposit.



Tephra sequence deposited between 1.3 and 2.0 ^{14}C kyr BP, Kamchatka, Russia.

The thick, upper light-coloured tephra layer is sourced from Shiveluch volcano (SH3) with an age of ~1.4 ^{14}C kyr BP, and the thick, lower pale brown tephra layer is sourced from Ksudach volcano (KS1) with an age of ~1.8 ^{14}C kyr BP.

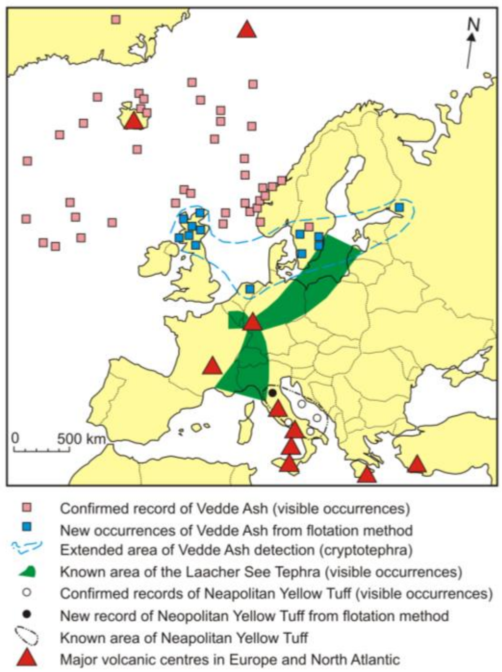
Both tephras are prominent Holocene marker beds throughout Kamchatka.



Macroscopic tephra displaying tractional sedimentary structures:

(A) Laterally continuous tephra bed within cross-stratified highly fossiliferous shallow marine sandy siltstones. Inset: Extensive burrowing and sharp but irregular upper and lower contact.

(B) Discontinuous lenses of pumiceous and crystal-rich sands, pumiceous granules and gravels within cross-bedded sands, Wanganui Basin, New Zealand.



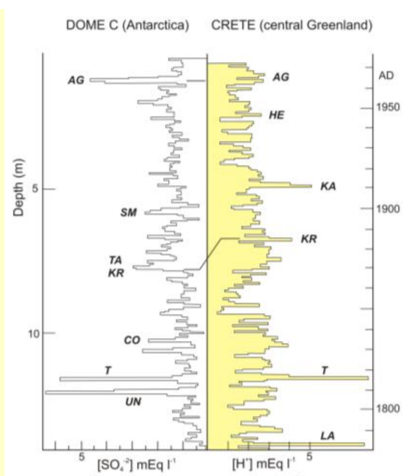
Field Characteristics
Microscopic

Distal tephra deposits, preserved as glass-shard and/or crystal concentrations in peat bogs, lake, marine or aeolian sediments, or ice-cores, or soils, may be invisible to the naked eye in the field.

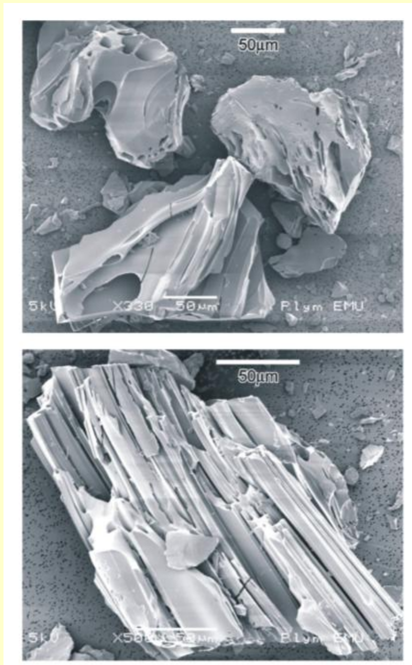
Such deposits, usually of ash grain-size, are referred to as ‘cryptotephras’

1-cm-thick visible tephra horizon identified within the NGRIP ice core, Greenland.

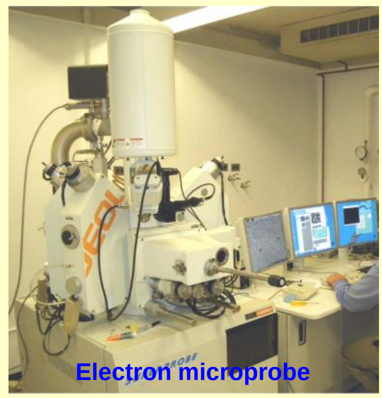
Field Characteristics
Chemical traces



Comparison of tephra horizons deposited in Greenland and Antarctic snow over the last 210 years. On the right-hand side the acidity profile (ECM measurements) obtained at Crete, central Greenland, is shown. On the left hand side are shown the sulphate measurements obtained at Dome C. The following eruptions are identified: Agung (*AG*), Santa Maria (*SM*), Tarawera (*TA*), Krakatoa (*KR*), Coseguina (*CO*), Tambora (*T*), Unknown (*UN*), Hekla (*HE*), Katmai (*KA*), and Laki (*LA*).

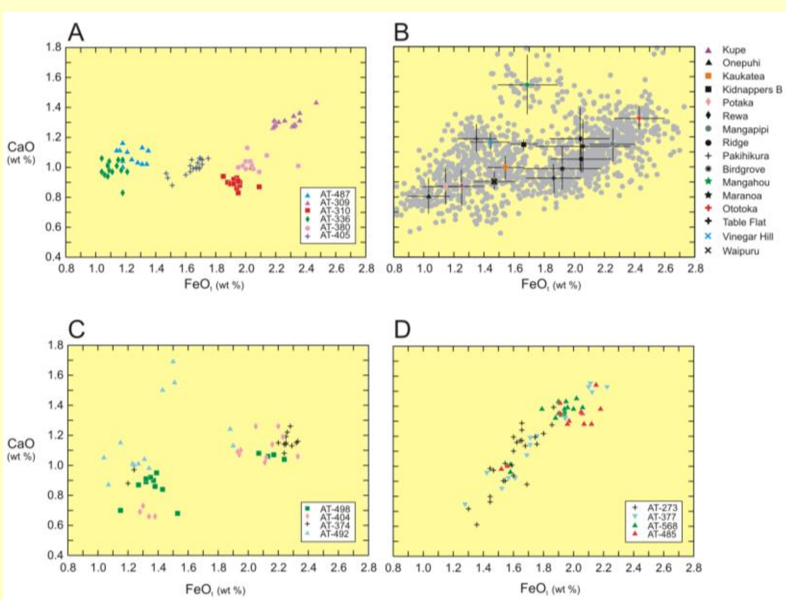


Mineralogical & Geochemical Characteristics

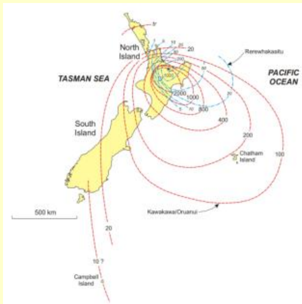


Glass Shard Geochemistry

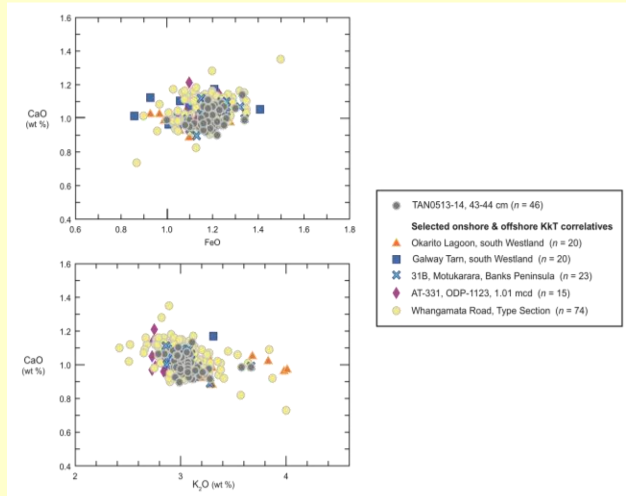
Examples of the glass composition in rhyolitic tephra beds determined by electron microprobe analysis.



Kawakawa/Oruanui Tephra (KOT)

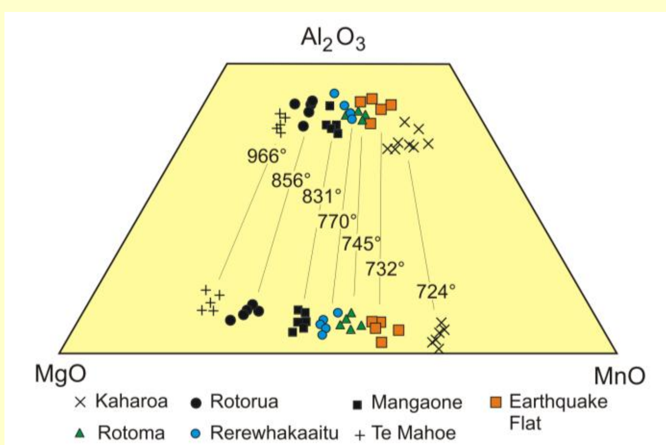


Map of distributions of Kawakawa/Oruanui (red dashed line) and Rerewhakaaitu (blue dot-dash line) tephras. Isopachs in centimetres.



Correlation of onshore & offshore KOT based on selected major element glass geochemistry

Fe-Ti oxide chemistry



The minor element composition of spinel (Al_2O_3-rich phase) and ilmenites (Al_2O_3-poor phase) in rhyolite tephra from Okataina Volcanic Centre, demonstrating their fingerprinting ability. Also shown is estimated eruption temperature based on equilibrium between spinel and ilmenites.

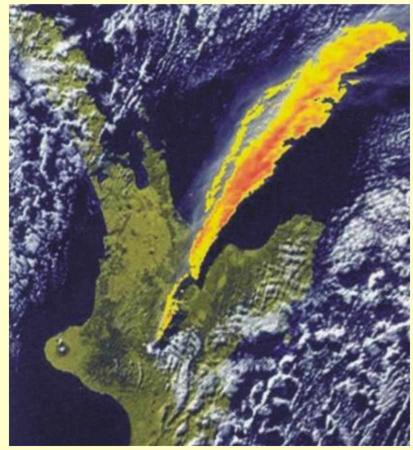
SUMMARY PART 1

'Tephra' derives from a Greek word *tephra* meaning 'ashes'. It is a collective term for the explosively erupted, loose fragmental (pyroclastic) products of a volcanic eruption, and encompasses all grain sizes.

Tephra deposits are erupted over geologically-short time periods & they can be spread widely over land and sea to form a thin blanket that has the same age wherever it occurs.

Therefore, once identified by its mineralogical and geochemical properties, a tephra layer, unless reworked, provides a time-parallel marker bed or isochron.

Tephras are now routinely detected & dated in terrestrial, marine and ice-core records throughout the world in both macroscopic & microscopic (cryptotephra) forms.



Eruption plume of Ruapehu volcano, central North Island, New Zealand, as seen from space in 1995.