

Volcanic Stratigraphy

Volcano-stratigraphy of La Garrotxa monogenetic volcanic field (NE of Spain)

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La Garrotxa monogenetic volcanic field (GVF) forms part of the Catalan Volcanic Zone (CVZ), located at the NE of the Iberian peninsula, which is one of the provinces of the Quaternary alkaline volcanism of the European rifts system. The GVF corresponds to an area of about 100 km² located between the main cities of Olot and Girona. This basaltic volcanic field comprises more than 50 monogenetic cones including cinder and scoria cones, lava flows, tuff rings, and maars, ranging in age from 0.6 Ma to early Holocene. Strombolian and phreatomagmatic episodes have combined in the construction of most of these cones, which exhibit a wide range of deposits and eruptive sequences. Combining field work, stratigraphic logging of water wells and geotechnical drillholes, and the application of shallow geophysical methods, we have been able to establish by the first time a volcano-stratigraphy of the area that identifies the products of each single eruption, their relative stratigraphy and their areal extend. This volcano-stratigraphy constitutes an essential tool for understanding the evolution of this volcanic field and for a volcanic hazard assessment.

Keywords: volcano-stratigraphy, monogenetic volcanism, Garrotxa volcanic field, hazard assessment.

Stratigraphic methodology for the new geological map of Etna volcano

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The new geological map of Etna volcano at 1:50,000 scale is completely based on a stratigraphic approach, using three different kinds of stratigraphic units, lithostratigraphy, lithosomatic and synthemetic units, evidencing the complex setting of the spatial and temporal evolution of the volcanic system and the surrounding environment. The relationships between the different categories of stratigraphic units are shown in Fig. 1, where the temporal extension of certain long-living and eotopic units is represented with blue arrows, while temporal and stratigraphic uncertainty is indicated by red arrows. The lithostratigraphy represents the main stratigraphic criterion used for the identification of the volcanic bodies during the field survey and the cartographic representation. Then Unconformity Bounded Units were applied to group lithostratigraphic units into synthems. In addition, lithosomes were exploited to better represent the spatial localization of different eruptive centres according to their morphology. On the whole, we identified 27 lithostratigraphic units, grouped into 8 synthems, and 9 volcanoes. In detail, effusive and explosive deposits generated by each eruption of Mongibello and, partially, Ellittico volcanoes were mapped as flow rank, and for the last 2000 years grouped in 3 lava flows time intervals using labels and boundaries that allow to identify each flow.

This stratigraphic framework represents the best synthesis of the geological evolution of Etna volcano using the main unconformities recognized within its complex volcanic succession. The detailed reconstruction of the past eruptive activity allowed compiling the most accurate dataset in particular of the Holocene eruptions of Etna volcano, which will enable significantly improving the volcanic hazard assessment, together with petrological interpretation of erupted magmas and geophysical modelling of the volcano plumbing system.

Keywords: Mapping volcanoes, Synthemetic unit, Lithostratigraphy, Lithosomatic unit, Geological evolution.

What does “volcanoclastic” mean in a distal sedimentary succession?

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All along the Oligocene Alpine foreland (Molassa) and foredeep basins, thick volcanoclastic sequences of distal sedimentary successions are exposed. By now, their significance is still ambiguous, also because almost none volcanic center is preserved. In this review, we take in account different features of the torbiditic sequences to try to discriminate possible syn magmatic signal in them.

Keywords: explosive volcanism, volcanoclastic signal, Oligocene Alpine Molassa / foredeep.

Mineral phases as a tool for robust correlation of proximal-distal tephra in the Central Mediterranean Area

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Tephra layers and Quaternary sedimentary archives constitute a mutual and integrative system capable of providing relevant information for both volcanological (i.e. hazard assessment) and Quaternary science research (i.e. stratigraphy, paleoecology, paleoclimatology).

The Central Mediterranean represents an area extremely suitable for tephrostratigraphic studies because of the several volcanic sources characterized by explosive activity during the Quaternary (Fig.1). Tephra erupted by these volcanoes have been recorded by the main marine and terrestrial sedimentary archives; they have been surveyed along all the circum-mediterranean area as far as the Eastern Europe. An Example of far distance deposition of tephra can be provided by the Campanian Ignimbite that reached the Russia plain.

Comparative analysis of glass from proximal and distal deposits sometimes fails in providing a reliable criterion to recognize the source of a tephra (or the related eruption), owing to very similar major element compositions that make difficult discrimination on a chemical basis. This is particularly critical for both the Campanian trachytic products (i.e. those erupted from Campi Flegrei, Somma-Vesuvius and the Ischia island volcanoes) and for the calc-alkaline rhyolitic products of the Aeolian Islands. To solve this problem, the evaluation of both the mineralogical association, and the chemistry of the mineral phases included in the proximal tephra is required. With this approach some distinguishing features can be revealed and, if matched in the distal counterpart, would represent a valid tool for robust correlations. Some successful examples for the application of the method are (i) the products of Colli Albani containing both leucite and nepheline and not feldspar, or (ii) the Agnano-Monte Spina eruption ascribed to the Campi Flegrei on the basis of biotite absence.

Our results indicate that the collection and collation of mineral phase compositions and assemblages in a GIS database is very promising to improve correlative potential of distal tephra layers in the context of the Central Mediterranean area.

Keywords: Central Mediterranean, Quaternary volcanoes, tephra correlation, distal-proximal deposits, mineral phases.

Multidisciplinary approach to the Holocene flank eruptions in Tenerife (Canarias)

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A multidisciplinary approach has been applied to study the eruptive fissures on the slopes of the main volcanic edifices in Tenerife. Our work concentrated on the youngest portion of these cones, their age, and distribution. In order to achieve this goal, a detailed fieldwork has been carried out by means of a 1:5000 scale geological map of volcanic deposits and structural features. An area of about 10 km² has been surveyed up to now. Sampling in the field has been addressed to the age solving of the main recent volcanic record (last 8000 yrs BP) by means of the archaeomagnetic method. In addition, petrochemical and rheological analyses are on the road.

Keywords: Geological map, Archeomagnetic datings, Eruptive fissures, Scoria cones, Hazard assessment.

Original detection methods for tephra layers and cryptotephra

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The building of independent and accurate chronologies is crucial to correlate environmental and climatic changes as reflected in biotic as well as abiotic signal from continental lacustrine sediments. The use of tephra, which are instantaneous and time-synchronous atmospheric deposits, as time-parallel markers, allows to build independent regional and inter-regional high precision correlations. The development of effective rapid methods to detect tephra layers in sedimentary records of various compositions is a challenge. Many classic methods for detection of tephra layers, like regular sampling or magnetic susceptibility measurements, have shown their limits. Regular sampling takes a long time, and finding tephra layers uncertain. Moreover magnetic susceptibility is ineffective when tephra layers are made of volcanic glass shards of differentiated magma composition.

This study proposes three original methods to detect tephra layers: XRF, CT imaging and quantitative sulfur analysis. XRF permits the differentiation between tephra layer composition elements and sediment. CT imaging may also be used to see 3D sedimentary structures. Sulfur analysis allows us to discuss the environmental impact of degassing in volcanic eruptions. These methods can be used successfully to detect tephra layers of various chemical compositions in peaty and carbonated deposits.

Keywords: Tephra layer, tephrostratigraphy, XRF, radiography, CT imaging, sulfur, Jura plateau, french Massif-Central.

A sequence stratigraphic study in a complex volcanic area (Campania, Italy)

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The Campania Volcanic Zone, located on the eastern margin of the Tyrrhenian Sea, is a region characterised by active volcanoes and ignimbrite deposits. Well known are the active volcanoes of Campi Flegrei, Vesuvius and Ischia. Over the last 15 years, offshore Campania were discovered numerous volcanoes, domes, pyroclastic units and debris avalanches deposits that permit to identify new volcanic fields and quantify the volume of ignimbrite deposits.

Sequence stratigraphy is focused on analysing change in facies and geometric character of strata and identification of key surfaces to determine the chronologic order of basin filling. The use of a sequence stratigraphy approach for the interpretation of outcrops, well log data and seismic reflection profiles with different resolution and penetration permit to correlate areas characterised by heterogeneous data sets. The sequence stratigraphic approach was applied in this complex volcanic area. The study was performed by means of interpretation of seismic reflection profiles, well logs and outcrops, and the 3D modelling of geological surfaces performed using Kingdom® software (copyright IHS).

The results are the discovery of buried volcanic units, the reconstruction of regional geologic cross sections, the individuation of a coherent chronostratigraphic framework and the stratigraphic relationships between different volcanic fields. This study furnishes a complete volcanic evolution of the Campania Volcanic Zone, defines the abrupt changes of the sedimentary environments and consequently individuates the volcano-tectonic subsidence events, and finally updates the Quaternary stratigraphy of the volcanic events.

Keywords: Seismic reflection profile interpretation, Well log interpretation, Sequence Stratigraphy, Campania Volcanic Zone, Italy.

Regional implications of new U-Pb zircon ages from rhyolitic ignimbritic deposits and andesitic flows of Permo-Carboniferous basins in Southern Pyrenees

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The U-Pb datings of zircons provide the essential data for determining the precise ages and timing relationships of Late Palaeozoic volcanic activity and contribute to improving the stratigraphy of the Southern Pyrenees (ca. 304 Ma to ca. 282 Ma- Upper Carboniferous–Lower Permian). The reported ages for the Erill-Castell, Estac, Cadí and Castellar de n'Hug basins fit quite well with the time interval of magmatism related to an early north-dipping subduction of the Western Paleotethys Ocean, the subsequent development of Iberian orocline (Variscan cycle), and the large-scale bending and blocking of the Paleotethys Ocean subduction East of Iberia (Cimmerian cycle) during the complex evolution of Pangaea.

Keywords: NE Iberia, Permo-Carboniferous basins, rhyolitic-andesitic volcanism, U-Pb zircon geochronology.

Geological setting, volcanic stratigraphy, and flank failure of the El Estribo volcano, Pátzcuaro, Michoacán, Mexico

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The El Estribo volcano is located within the Michoacán-Guanajuato Volcanic Field in western México. Previous works considered this volcano as a single cinder cone. The results of this study, however, suggest that it consists of a basal shield volcano crowned by a cinder cone. The upper cinder cone has a 1.2 km base and a 0.5 km crater with a maximum altitude of 2450 m a.s.l. The shield volcano has a basal diameter of 3.6 km and it is cut by an E-W oriented normal fault. Several landslides have been triggered at fault scarp resulting in debris avalanche deposits emplaced to the north into the Pátzcuaro Lake.

Refined stratigraphic of “El Estribo” volcano comprises three main lithological units (Flv-la; E-Sh; E-Ci): 1) three different sequences of lacustrine and ash layers with ages >30000, between 10000 and 30000, and < 3000, respectively (Flv-la); 2) basaltic-andesitic lava flows of the shield volcano (E-Sh); 3) stratified scoria fall, reworked beds, and scoria falls interbedded with pyroclastic surge deposits (E-Ci) covering a paleosol dated at 28360 ± 170 BP (Ps).

The southern shore of Pátzcuaro Lake is characterized by at list two debris-avalanche deposits, with marked differences in morphology. The first one, dated at 28000 yr BP, presents an emplacement length of 3.2 km and a H/L of 0.06. The second one, dated at 14000 yr BP has a maximum run-out of 2 km and a H/L of 0.08.

The causes of these collapses are still under study and may imply different factors as: i) destabilization during the emplacement of the cinder cone; ii) different rock strengths between the involved rocks and sediments; iii) seismic events; and iv) slope instability.

Keywords: geological evolution, stratigraphy, flank collapse.

Geology and stratigraphy of the Cerro Prieto Volcanic Complex, Baja California Norte, México

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New mapping and stratigraphy of the Cerro Prieto Volcanic Complex indicates that it was constructed by several events: 1) The beginning was characterized by the emission of dacitic lavas that interacted with water-saturated sandstones, producing brecciated lavas; 2) Then, effusive activity formed a lava dome that was destroyed by a phreatic eruption, producing a lithic fallout and a 300 m wide summit crater; 3) Afterwards, the volcano recorded effusive activity with the emplacement of three domes and a fissural lava flow; 4) Subsequent erosion of the volcanic complex resulted in the emplacement of debris flows around the complex. These magmatic events occurred around 80 ka in a relatively short period of time. All rocks of this complex are made of porphyritic lavas

with phenocrysts of opx + plg + qtz + iron oxides >> ghost of amphibole, embedded in a groundmass with plagioclase microlites and glass, with a dacitic chemical composition (67-69 wt. % silica).

Keywords: Volcanic stratigraphy, geochemistry, Cerro Prieto, Mexico.

Another look to the mechanisms of formation of ash aggregates in pyroclastic deposits

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Ash aggregation has been a subject of great interest in volcanology, due to its importance in removing the finer-grained fraction of the fragmented material generated during explosive eruptions. In such events, the amount of ash (< 2 mm) represent a great fraction of the total erupted mass, and is dispersed in the surrounding atmosphere by vertical plumes and/or pyroclastic density currents (PDCs). Aggregation enhance sedimentation, reducing the residence time of solid particles in the atmosphere; therefore understanding the processes that govern particles accretion is of critical importance for hazard assessment. Observations and experimental studies to date indicate that water, either in liquid or solid states, is able, in certain proportions, to provide the strongest bonds between particles, which are necessary to form spherical to oblate aggregates able to survive the impact with the ground and to be preserved in pyroclastic deposits. On the contrary, electrostatic attraction between particles only forms dry, loosely bound aggregates, several hundreds microns in size, which rapidly disintegrate.

In general, aggregates are sub-to-few mm in size, even if maximum sizes of several centimeters are sometimes reported. Nevertheless, the individual accreted particles rarely exceed 1 mm. Several types of aggregates were described in the pyroclastic density currents produced during the 1982 eruption of El Chichón volcano (Mexico), characterized by the injection of 8 million tons of SO₂ in the atmosphere, responsible for a 5-6°C warming in the tropical lower stratosphere. In such aggregates individual components are strongly cemented by a S-rich film among which particles between 1 and few mm in diameter are common. Even if not visible at the outcrop scale, they represent a consistent proportion of the deposits and are extremely resistant to disaggregation, eventually attesting their capacity to survive not only impact on the ground during falling, but also collisions with other clasts. Their similarities with aggregates found in sulfur cones at Poás volcano suggest that liquid sulfur is the cementing material. The explosive ejection of sulfur may occur in volcanoes with active hydrothermal systems. The ability of liquid sulfur to cement particles >1 mm in diameter indicates that size-fractions of lapilli can be efficiently removed from eruptive clouds at distances of few km from the vent, and have important implications for hazard assessment.

Keywords: Aggregation, liquid sulfur, eruptive clouds, hazard assessment.

Stratigraphy of the Coranzulí Caldera

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The Coranzulí caldera (23°S-66° 15'W) is a large volcanic complex located in the eastern part the Northern Puna, Central Andes. Its location was controlled by the intersection of two lineaments with NW-SE and NE-SW strikes. The Coranzulí caldera emitted three major and a smaller pyroclastic units related to the caldera formation and three lava flows that represent the final stages of its eruptive cycle. The pyroclastic sequences are dacitic and crystal-rich, they are moderately to intensely welded and the pumice fragments are highly vesiculated. The ages obtained for the ignimbrites range between 6.8 ± 0.15 Ma and 6.45 ± 0.15 Ma.

The absence of fall-out deposits indicates that a relatively low-height eruptive column fed the pyroclastic sequences. The deposits cover an area of 1,900 km² and have 400 km³ (DRE).

Keywords: Coranzulí, Northern Puna, caldera, Central Andes.

The use of stratigraphic data for the mitigation of hazard at volcanoes: the example of Somma-Vesuvius (Italy)

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A review of the geological methods used for constructing hazard maps at Somma-Vesuvius is here presented. It deals with the description of methodology and stratigraphic data used for built up hazard maps for pyroclastic density currents and proximal and distal fallout of pyroclastic material.

Keywords: Somma-Vesuvius, volcanic hazard, volcanic stratigraphy.

The large explosive activity of Mount Etna as written in distal tephrostratigraphy

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Mt Etna is world famous for being the most active and the highest volcano in Europe. Lava flows and weak explosive eruptions characterise its activity, but intermediate to large explosive eruptions punctuated its eruptive history. Marine and lacustrine distal records are excellent archives for the recognition of past large explosive activity at Mt Etna, as testified by several recognition of distal tephra layers of Pleistocene to Holocene age. These data are, to date, neither organised nor correlated to the proximal stratigraphic and chronologic record. Here, we propose the reorganisation and the correlation of the distal tephra layers from Mt Etna in order to decipher time and frequency of its major explosive eruptions in the past.

Keywords: Mount Etna, tephrostratigraphy, explosive eruptions, Mediterranean area.

Stratigraphy of the Dej Tuff, Transylvanian Basin, Romania

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Due to its prominent and easily recognizable features the Dej Tuff is a major marker horizon within the up to 4000 m thick pile of the Neogene sedimentary fill of the Transylvanian Basin. It is widely cropping out along the western, northern and southern margins of the basin and is found in drillings throughout the whole basin. The Dej tuff displays extremely variable thicknesses (from a few meters up to 116 m) and a complex internal architecture. Biostratigraphic investigations and radiometric dating place the Dej Tuff at ca. 15 Ma within Badenian (Middle Miocene). Detailed lithostratigraphic studies revealed that it consists of a variable number (2 to 5) of upward-fining lithological sequences, reflecting succeeding major depositional stages. They are composed of 3 main lithotypes of coarse to fine-grained volcanoclastic deposits containing variable amounts of admixed non-volcanic material: 1) meters-thick massive to vaguely bedded coarse deposits rich in terrigenous non-volcanic material, originated from submarine debris-flow events, 2) meters-thick massive to bedded tuffs poor in or without admixed non-volcanic material generated by high-density turbidite currents, and 3) meters-thick sequences of alternating centimeters to decimeters-thick tuff and clay/marl layers deposited from a succession of low-density turbidity current events. All these lithological entities are laterally discontinuous, lens-shaped bodies resulted from subaqueous reworking and redeposition of large volumes of primarily mostly land-deposited loose tephra during a number of depositional events. Primary deposits generated by pyroclastic density currents are found sporadically (e.g. at Magura Ciceu).

A detailed compositional investigation of the Dej Tuff in the Cepari exposure, including mineral chemistry of the primary magmatic main and accessory rock-forming minerals, allowed to pointing out compositional sequences within the tuff complex which do not fit the depositional sequences. The three compositional sequences identified contain mineral assemblages displaying systematic upward variations in a number of chemical features, such as the types and frequency of mafic minerals, An% contents of plagioclase crystalloclasts, composition of Fe-Ti oxides and of REE-bearing minerals (i.e. allanite). Interpretation of these findings led to the consideration of compositional and thermal zonation of the magma chamber(s) from which the magmatic component of Dej Tuff originated. Furthermore, these results allow for speculations related to the number (3) and type (Plinian) of eruptive events generating the pyroclastic material reworked in the depositional sequences. The genetic model explaining these findings considers that the compositional sequences found in the reworked deposits actually mimic the magma chamber zonation features (upward-decreasing temperatures and upward-increasing SiO₂ and alkali contents) after reverting the presumed upside-down zonation features in the primary pyroclastic deposits.

Keywords: volcanic stratigraphy, Dej Tuff, compositional sequences, magma-chamber zonation.