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Gas migration along fault systems in the Latera natural analogue (central Italy): implications for CO_2 geological storage.

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Well-sealed and isolated natural CO_2 accumulations provide confidence in the potential for safely storing anthropogenic CO_2 for long time periods in deep geological formations. Leaking natural CO_2 accumulations, on the other hand, represent spatially-large, long-time-scale natural laboratories where issues related to gas migration mechanisms and pathways, system evolution and self-sealing processes, and gas release distributions and quantities on surface can be studied and quantified, information that can all be used to select the best geological storage sites, to realistically assess risks, and to make the sites as safe as possible. One such example of the latter type is the geothermal field located at Latera, in central Italy. Here CO_2 is thermo-metamorphically produced at great depths, after which it migrates along fault systems and is released at surface from individual gas vents in a valley that has been inhabited for hundreds of years. The occurrence of gas permeable fault systems, both buried and visible in outcrop, in this area give a unique opportunity to study how various features (such as fault geometry, size, style, age, activity, and secondary mineralogy) control the heterogeneous migration and channelling of gas along a structure.

In the past, extensive soil gas and gas flux measurements have been conducted on the Latera test site by the authors during the EC-funded NASCENT project. The present work has been performed within "CO2GeoNet", an EC-funded Network of Excellence on CO_2 geological storage. In particular, a structural survey was conducted in the area and then a soil gas and CO_2 flux survey was performed across specific fault systems having associated gas vents of different geometries, sizes and leakage rates. The study was conducted in order to compare flux and species behaviour above these faults to better understand migration processes.

The structural survey conducted in the Latera area recognised two main trends (fractures and faults), probably connected to the extensional regimes that characterized the more recent tectonic evolution of the Tyhrrenian margin. The similar trends observed for the structures and various gas emission points highlight this cause and effect link. Based on the obtained data it is proposed that the extensional fault system consists of normal faults trending N10˚E, parallel to the best developed fracture system, and N50˚E fractures and faults that could represent a tear fault system. The extensional tectonic setting is characterized by main fault surfaces having localised vertical offset, and by transfer normal / strike slip faults oriented at high angles to the main faults. These latter faults transfer the total offset from one main fault to another. According to the direction of extension on the main faults, the transfer faults can be normal or at an oblique angle to the main system, and have oblique to strike slip kinematics. The transfer zone can also be more complex and can be formed by a soft relay ramp, tear faults or both. In the studied area the N50˚E fractures and faults seem to represent such transfer structures.

The gas geochemistry surveys performed across both visible and buried fault systems highlighted CO_2 flux values ranging from 100 to 7000 g/m^2/d, and soil gas concentrations of CO_2 from 4 to 100%, H_2S from 10 to 2500ppm, CH_4 from 4 to 1500ppm and He from 5.5 to 9ppm, with wide ranges of values observed over short distances. At this site there appears to be a correlation of surface gas release, and therefore secondary permeability at depth, not only along the length of the fault structures but perhaps more importantly at the intersection of two faults or at the junction between the main faults and the transfer faults. In addition, where faulting and fracturing is exposed in outcrop, there is a different gas migration signal across different zones of the fault itself, which include fine-grained cataclastics with deformational bands and breccias containing blocks of host rock. In particular the core of the fault shows iron staining and discolouration which has clearly been caused by fluid migration, with localised secondary precipitation observed along some slip planes. Above buried faults an alignment of isolated venting features have been defined, highlighting the channelling process which controls the migration. As this site has an approximately 4m thick sedimentary package above the water table there is a clear modification in soil gas compositions relative to gas flux rates, as a lower flux increases residence times which in turn allows for microbial and redox reactions that can consume reactive species like H_2S and CH_4.