STRUCTURAL CONTROL ON THE FLOW AND ACCUMULATION OF HYDROCARBONS IN THE CARBONATE ROCKS EXCAVATED IN THE CENTRAL ROMAN QUARRY NEAR LETTOMANOPELLO, MAIELLA MOUNTAIN, CENTRAL ITALY

Atilla Aydin, Fabrizio Agosta, and Marco Antonellini
Rock Fracture Project
Stanford University

Abstract

The central Roman Quarry, an excavation of a little larger than a football field near Lettomanopello in Maiella Mountain, displays beautiful examples for how elements of a small normal fault zone control hydrocarbon flow and accumulation in a sequence of biocalcarenite units of the Miocene Bolognano Formation. In this contribution, we document the spatial relationships of the structural elements and hydrocarbon distribution along the fault zone. Finally we offer our preliminary interpretations on relative timing and mechanism of the faulting and the introduction of the hydrocarbons.

Introduction

The presence of hydrocarbons in the form of tar in the Bolognano Formation has been well known since the Roman time. This contribution and the following field trip are thanks to the Romans who excavated the quarry, which reveal the lithological and structural relationships that otherwise would have been covered by soil and vegetation. In this study we focus on the central of the three quarries aligned in a NW direction. The Bolognano Formation of Lower Miocene-Tortonian age is exposed within the quarry and in the immediate surroundings (Fig. 1).

The Bolognano Formation is a detrital biocalcarenite often including glauconite. The beds of this formation are as thick as 2 to 3 m, and contain bryozone and ostracods. The upper levels of the Bolognano Formation are comprised of marly calcarenites with thin beds that are on the order of a few tens of cm thick, and fossiliferous calcarenites. The total thickness of this formation varies between 200 and 300 m. (Vezzani and Ghisetti, 1999). Based on the fact that the quarry is located near the top of the formation, the exposed section represents the calcarenites and marly calcarenites of about the upper 100 m. Also see the geologic column for the Maiella area in Fig. 3 of the (introduction, this volume) and note that this formation caps the entire Maiella series that we will see at the next stop.

The objective of this study is to decipher the structural control on hydrocarbon distribution in the quarry. Although the lithology has a significant impact on the distribution of hydrocarbons in the Quarry, our primary interest is to understand how structural elements interact with the hydrocarbons.

Figure 1. Geologic map of Lettomanopello and its surroundings. The study location is also shown (rectangle). Modified from Servizio Geologico Italiano, (1970).

Structural control on hydrocarbon distribution and flow in the central Roman Quarry

The first order structural feature in the quarry is primarily a normal fault structure trending northwesterly with north-eastern side down thrown (Fig.1). Although not shown in the published geological maps of the area, it is a fairly long continuous structure. The orientation and the sense of the fault are not unusual for the area. In fact, when mapped on an existing detailed map (Fig.1), the zone lies in the extension of north-eastern strands of the Lettomanopello fault zone which is more than 10 km in length and 5 km in width and has a few hundreds of meters of cumulative throw.

When viewed closer, this structure may be subdivided into two zones (Fig. 2), here informally named as the southwestern (SW) and northeastern (NE) zones.
Figure 2. Major fault structures and hydrocarbon distribution in the quarry.

Figure 3 shows a cross-sectional view of the two fault zones and the associated hydrocarbon belts of varying types and intensity. The fault zones are connected by diagonal faults in the SE wall of the Quarry and eventually merge into one narrow zone in the upper levels of the NW wall. Using a key marker that includes a characteristic downlap horizon we identified across the quarry, the SW zone has a total offset of about 40 m whereas the NE zone of about 10 to 15 m (Fig. 4).

Even without relying on the offset values, it is apparent that the SW zone has developed better as we will characterize it below.

**Structural elements and hydrocarbons**

Both fault zones display characteristic elements of other comparable faults that do not contain hydrocarbons. A major strand of the SW fault zone is excavated at upper level of the quarry, at about 40 meters SE from the intersection of the SW and NW walls (Fig. 2 and 3). Along this strand (Fig. 5a), exceptional examples of multiple slip surfaces (Fig. 5b and c) associated with tar filled breccia zones can be observed. The photograph in Fig. 5b shows a slip surface with a fine grained fault rock that does not show any hydrocarbon by naked eye. The photograph in Fig. 5c shows a layer of hydrocarbon of a few cm in thickness adjacent to the slip surface with fine grained, tar free fault rock. Further to the southeast, another strand of the same fault zone is represented by two subparallel slip surfaces bounding a tar filled breccia zone of about 2.5 m in thickness (Fig 5d).

The NE fault zone (Fig. 3) displays different characters than the SW zone. The NE zone includes several slip surfaces with adjacent tar filled breccia, which is usually in triangular shapes at the intersections.
of individual faults (Fig. 6a) some of which are not parallel to each other (Figs. 6b and 6c).

The most striking character of the NE zone is the broad brecciated body that localizes in the upper levels of the SE wall of the quarry (Fig. 3), where this zone crosscuts thinly bedded marly units. The marly units at this location are interlaced by bedding plane slip faults, sheared pressure solution seams, and sheared joints. Some of the relatively large faults in the marly units at this location have not been yet mapped.

The continuation of the NE fault zone at the entrance level of the SE wall of the quarry (Fig. 7a) displays excellent examples of slightly sheared fractures and fracture clusters. We present three cases illustrated in detailed maps of the various structural elements and their relative crosscutting and abutting relationships (Figs. 7b, c and d). These cluster zones including sheared pressure solution seams and their tail pressure solution seams were invaded by hydrocarbons (Figs. 7b, c and d).

What we learned from these relationships shed light on the mechanisms of fracturing and faulting, which produce fracture clusters, fragmentation, and broad breccia zones also observed in other locations. For example, several fracture cluster zones with limited offset are well exposed on the NW wall of the quarry (Figs. 8a and 8b). The northeastern most of the cluster zones exposed along the NW wall sketched in Fig. 8c is characterized by a normal offset of about 0.5 m, and appears to be responsible for the opening of pathways for hydrocarbons.

Although it is not our goal to characterize the petrophysical properties of the lithological units, we note the intimate relationship between fracture and fault flow paths and lithologically favourable flow units. This is well displayed by the map pattern of fault zone geometries and the units with noticeable hydrocarbon
impregnation (Figs. 2 and 3). The sketch in Fig. 8c is a small-scale example illustrating this interplay. Fingers of hydrocarbon-impregnated porous lithologies spread away from the fault zone but die out at a short distance.

Figure 8. The continuation of the NE fault zone at the entrance level of the SE wall of the quarry.

Discussion and conclusions

The central Roman quarry, displays beautiful examples of how a small normal fault zone and related structural elements impact the hydrocarbon flow and accumulation in a sequence of biocalcarente carbonates. The preliminary major results of our study are summarized below. In addition, we compare these results with those obtained from a number of examples in clastic and carbonate environments.

- Brecciated and fragmented rocks in fault zones are good locations for hydrocarbons. Relays between parallel normal faults and triangular domains between intersecting faults provide positive correlation for hydrocarbon accumulation. An increasing permeability along these zones has been established for normal faults in clastic rocks (Davatzes et al., 2004). It is reassuring that similar structural settings in carbonates have similar properties.

- Slip surfaces may be conduits for hydrocarbons but the associated fine grained fault rock appears to be immune to hydrocarbon penetration. Again, this aspect is well established in clastic rocks (Antonellini and Aydin, 1994; Aydin, 2000) and agrees to what it has been documented for normal faults in platform carbonates (Agosta and Aydin, this volume).

- Fracture clusters are great locations for hydrocarbon concentration. This is again similar to what we have established in clastic rocks of the Bolivian fold and thrust belt (Flores et al., 2005).

- A little shearing goes a long way in terms of flow efficiency. We knew about this phenomenon from shearing of joint zones in clastic rocks (Taylor et al., 1999).

- The observations in this study provided additional support for pressure solution seams and sheared pressure solution seams are hydrocarbons flow pathways in a carbonate reservoir (Graham et al., 2005).

- Based on the lack of tar in fine-grained fault rock and a layer of tar adjacent to a slip surface, we conclude that the structures had formed before the hydrocarbons invaded the area.

- There is an intimate interplay between the structural flow paths and the adjacent lithological flow units for hydrocarbon presence and distribution. The level of hydrocarbon presence in what appears to be porous rock drop sharply away from the major fault zones. In fact, judging from the excavation pattern in the Quarry, it is obvious that the Romans were well aware of this relationship: They exploited the flow units in close proximity to, and in between, the fault zones. The Romans, however, appear to have problems, probably technical in nature, with the fractured and faulted zones. Well, who doesn’t?

- The question of the significance of this small fault zone for hydrocarbon flow remains to be further investigated. As noted earlier, the fault in the Roman Quarry is part of a larger fault system around the town of Lettomanopello. There have been reports for hydrocarbon occurrence along the Lettomanopello Fault in the Fosso San Angelo valley. We, however, do not know how common the phenomenon is.

- Finally, we do not have any information about the genetic origin of the hydrocarbon in the Quarry. This information may be useful for interpreting possible temporal relationships between the deformation and the introduction of hydrocarbons.

References


