A PORTRAIT OF CENTRAL ITALY'S GEOLOGY THROUGH GIOTTO'S PAINTINGS AND ITS POSSIBLE CULTURAL IMPLICATIONS

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Abstract. Central Italy has some of the most complex geology in the world. In the midst of this inscrutable territory, two people emerged--St. Francis and Giotto--they would ultimately change the history of ecology, religion and art by extoling the landscapes and geology of this region.

From Antiquity to the Middle Ages, man had a conflictual relationship with nature, seeing it as representing either divine or satanic forces. On the vanguard of a change in perspective toward the natural world was St. Francis of Assisi (c.1181-1226) who is now, thanks to his pioneering work, patron of ecology. He set forth the revolutionary philosophy that the Earth and all living creatures should be respected as creations of the Almighty.

St. Francis' affinity for the environment influenced the artist Giotto (c.1270-1337) who revolutionized art history by including natural elements in his religious works. By taking sacred images away from Heaven and placing them in an earthly landscape, he separated them definitively from their abstract, unapproachable representation in Byzantine art. Giotto's works are distinctive because they portray daily life as blessed, thus demonstrating that the difference between the sacred and profane is minimal.

Disseminating the new ideas of St. Francis visually was very effective, as the general populace was illiterate. Seeing frescoes reflecting their everyday lives in landscapes that were familiar, changed their way of thinking. The trees, plants, animals and rocky landscapes were suddenly perceived as gifts from the Creator to be used, enjoyed and respected. Further, Giotto recognized that the variety of dramatic landscapes would provide spectacular visual interest in the works. By including the striking landforms of central Italy, and portraying them accurately, Giotto allows us the opportunity to identify the types of rock in his frescoes and possibly even the exact location he depicted. In fact, it would be discoveries in the pink Scaglia Rossa limestone--depicted in Giotto's frescoes as pink buildings and used to construct the Basilica of St. Francis at Assisi--which would revolutionize the history of geology.

1 Introduction

For a number of years, an international group of scientists and artists have been exploring the many connections between Earth Science and Art. As a geologist, I have long appreciated an artists' ability to capture the beauty of the Earth in a painting, poem or sculpture. While I can analyze the rock formations and marvel at the mystery of the Earth's topography, it takes an artist to move me to tears by presenting their unique view of the

landscape. In doing so, an artist presents the Earth using the visual—a tool so powerful it can move the most naïve viewer to experience the divine nature of the Earth.

My fascination with St. Francis developed because of his revolutionary ideas regarding ecology, but I soon learned that without the illustration of his ideas in frescoes by Giotto, he might not have had such a powerful and lasting impact. The analysis of Giotto's frescoes from a geological standpoint was a challenge, as St. Francis' monasteries were located in central Italy, a region that has some of the most complex and still unexplained geology in the world. Yet, it was precisely this geology that made Giotto's frescoes full of geomorphological wonder. He integrated his figures into this dramatically disordered landscape, forming a compelling composition for any viewer. The scenes portrayed in the frescoes have survived 700 years, allowing modern geologists the opportunity to study and compare them to formations visible today. In fact, discoveries in the pink Scaglia Rossa limestone ended up being the key to solving some of the most perplexing questions in historical geology.

In order to appreciate the revolutionary ideas of St. Francis and Giotto, a background on the medieval ideas pertaining to nature will be discussed. A select number of frescoes will be analyzed geologically, with attendant historical information explaining the scene. Geologic maps which can be used as references for the cited locations are also included.

1.1 The Idea of Nature in the Middle Ages

In the Middle Ages, the practice of linking natural phenomena to divine or satanic forces was the norm (Artz,2014). Since nature's behavior could not be predicted or controlled, medieval man lived in a constant state of awareness of its capriciousness. In order to alleviate stress, a method of spiritual interpretation called "anagoge" was devised by medieval theologians, notably Hugh of St. Victor (c.1096-1141), to explain natural occurrences. This meant that one had to search for the of meaning God's messages in nature through the complex and oftentimes arbitrary symbolism He chose to use (Cadden,1995). It was thought that by deciphering and diffusing malefic symbols one could avoid disaster or, in the case of auspicious portents, obtain a fortuitous outcome. The search for meaning in nature was much more important than the search for "how nature works" as mechanisms were not valued (Chenu,1983). After all, God was in charge of everything and what he was doing "behind the scenes" didn't matter. As a result, men tried to become more empathetic and more closely aligned to nature to understand God.

1.2 St. Francis

In the early 1200's, a young man from Assisi named Giovanni di Pietro di Bernardone, but known to us as Francis, gained a following for his revolutionary ideas pertaining to a sympathetic view of nature. Francis lived in Umbria, a region of Italy which is green, fertile and infused with a palpable spirituality. He was born into a well-to-do family of cloth merchants. As a young man, he renounced his own material wealth, even taking the position that the Church do the same. He walked to towns and villages, espousing a simple way of life and encouraging a reverential attitude toward the natural world, for he

believed that nature was the mirror of God. He called all creatures his "brothers and sisters" and preached that people had a duty to protect and enjoy nature as the stewards of God's creation (French,1996). He constructed a series of monasteries (Fusarelli,1999) which were situated in forests or snuggled up against the sides of mountains (Fig. 1). His own cell and bed were carved out of rock. Francis was also a poet and an outstanding innovator in the history of Italian literature. In his *Canticle of the Sun,* believed to be the first work written in the Italian language, he praised God for creating "Brother Sun" and "Sister Moon".

Soon he attracted a group of followers which were organized into many religious orders for both men and women. He became so influential that the Pope had to acknowledge him and allow his orders (Order of Friars Minor, the women's Order of Saint Clare, the Third Order of Saint Francis and the Custody of the Holy Land) to be officially recognized by the Church.

Francis was so venerated that Pope Gregory IX canonized him in 1228, only two years after his death and ordered a basilica be constructed in Assisi. It was built with indigenous pink Scaglia Rossa limestone (Fig. 2) and completed in 1253. Astonishingly, this Scaglia Rossa limestone, depicted in Giotto's frescoes, held the key which would revolutionize the history of geology.

1.3 Giotto

The Pope ordered scenes of the life of St. Francis to decorate the interior of the basilica. It was covered with frescoes painted by several generations of Italian artists. Among the many famous names who worked in the Assisi basilica were Cimabue (1240-1302), Duccio (c.1255-1319) and Giotto (1267-1337). They sought to honor St. Francis by portraying his life in a series of frescoes which not only served a proselytizing function but changed the history of art. This one building became the most fruitful single training school and meeting place in the history of Western art (Moleta,1983).

Giotto's works were so revolutionary that today he is considered the founder of Renaissance art (Moleta,1983). But the seeds of this dramatic stylistic transformation were planted by Cimabue, who worked at Assisi during the Pontificate (1288-1292) of Nicolas IV, the first Franciscan Pope. Cimabue broke from the rigidness of Byzantine art where figures were rendered flat and one dimensional (Dall'Asta,2012). Instead, he made them more realistic by using proportions and shading for volume.

Giotto followed Cimabue's lead in changing the flat figures of the Byzantine art form, conducive to contemplation (Dall'Asta,2012), to a more relaxed style by showing man in a natural setting. He observed the landscape and sought to portray its beauty and order. He used painting techniques to depict figures more solidly, so that they would appear three dimensional and thus, created the illusion that they were moving through a landscape within the picture. Giotto integrated sacred images into the Earthly landscape, separating them definitively from their abstract representation in Byzantine art. By portraying daily life, the realm of the sacred appears to be diminished, but that of the

137 profane acquires a grand dignity and seriousness, which became Giotto's distinctive
138 characteristic.
139
140 Additionally, both Duccio, (a contemporary of Giotto's), and Giotto were among the first
141 to add a depth perspective to their paintings this was revolutionary, as the rules of
142 perspective had been lost in the Dark Ages (Blatt,1984). Duccio used modeling (playing
143 with light and dark colors) to reveal the physique beneath the clothing's heavy drapery.
144 Hands, faces and feet became more rounded and three dimensional, giving his figures
145 vitality. Giotto used various techniques, such as presenting his buildings obliquely to take
146 up more space in depth, and presenting his figures with volume, scale and perspective to
147 evoke realism (Egerton, 1993). The two artists also placed their figures within natural
148 settings paying special attention to plants, trees, animals and making detailed rock
149 formations an integral part of the scene. As a result, their figures interacted with one
150 another, creating a sense of fluidity and movement in a realistic landscape, which was
151 astounding to the medieval viewer.
152
153 The inclusion of natural elements in visual art as a method of disseminating the new ideas
154 of St. Francis was very effective, as the general populace was illiterate. Seeing frescoes
155 reflecting their everyday lives in familiar landscapes changed their way of thinking
156 (Panofsky,1997). The trees, plants, animals and rocky land forms which had never been
157 valued suddenly became part of the incredible universe that God had created (Crombie,
158 1990). The Earth, and all things living upon its glorious terrain were gifts from the Creator
159 to be used, enjoyed and respected. Duccio and Giotto used nature as a symbol, as the
160 stage on which the mystery of life, both spiritual and temporal was played out. A lake, a
161 mountain range, a valley, depicted in a realistic manner would make the viewer identify
162 with the painting. With enough detail, the viewer could find any number of things that
163 reminded him of his village, farm or pasture. His journey of discovery would make him not
164 only feel a kinship with the work, but also a sense of conviction that the work was real.
165 The authenticity of the landscape contributed to disseminating the gospel by convincing
166 the viewer that the sacred message contained therein was valid, be it Christ's birth or
167 crucifixion or an episode in the life of a saint. And so, the depiction of these sacred scenes
168 acted as a catalyst for changes in Western piety as well as Western art (Moleta,1983).

169 Considering how venerated Francis was, one would think that Giotto would portray him
170 as a sacred figure surrounded by elegant surroundings, or embellished churches worthy
171 of exalted adoration. But Giotto could not do this because of the way Francis lived. The
172 stories and legends pertaining to his life and the humble places which he inhabited
173 required Giotto to place him in nature to depict his life accurately. So, we see in Giotto's
174 works the visual story of the ecological movement started by Francis.

175 In looking at the geology of central Italy, which Giotto portrayed in the scenes of the life
176 of St. Francis, we can see that he had a keen eye for geologic formations and took the
177 time to portray them realistically. These regions have some of the most complex geology
178 in the world, for the Apennine Mountains are not only seismically active but are being
179 contorted by forces of both compression and extension. There are faults, upthrusts and

180 nappes in the area, all of which displace strata, making it difficult for geologists to interpret
181 the regional geology. Yet in Giotto's works we see that he found these unique geologic
182 formations perfect for providing visual interest, yet accurate enough for geologists to
183 identify the rock types and speculate as to the exact location represented in the scenes.
184 To better understand the placement of the selected Franciscan monasteries and Giotto's
185 portrayal of the landscape refer to the geologic maps at the end of the article.

186 **1.4 Geology**

187 The Apennines, which form the backbone of the peninsula are some 1,200 kilometers in
188 length. They were formed some 20 Mya by processes which have not been completely
189 understood even today, in that they were formed both by compression and extension. In
190 the east, anticlinal ridges formed from thrust faults create a series of progressive folds,
191 one after another, while in the west, fault block mountains are created by normal faults
192 which slice out of the deep crust (Pizzorusso,2013).

193 The folds in the Apennines are caused by thrust faulting (Fig.3) where the thrust cuts
194 upward at about a 30-degree angle called a ramp. This wedge of thrust-up rock is forced
195 into the shape of an anticline and thus the Apennine ridges are ramp anticlines. This
196 range of large anticlinal folds includes Monte Subasio the location of Assisi (Lena,2014).
197 They extend from southwest to northeast. This orderly sequence occurs when material
198 deposited while building the anticline becomes too large for continued displacement and
199 the thrust fault slices a new ramp along weaker strata. The process continues, with a set
200 of parallel folds visible at the surface forming "propagating fold-thrust belts" which slice
201 out of the deep crust (Alvarez, 2008).

202 In the Apennines, as the migrating compressional front moves northeastward (the
203 anticlines get younger from Gubbio to the Adriatic Sea), there is an extensional front
204 following behind (about 100 km to the rear). When the extensional front arrives, the fold
205 is cut apart by normal faults and subsides as the underlying strata is stretched thin. The
206 most likely explanation for this dynamic is that the lower part of the continental crust peels
207 off and sinks. This hypothetical process is called "delamination" (Alvarez, 2008).

208 As noted previously (Fig. 2) the Scaglia Rossa limestone was used in the construction of
209 the Basilica of St. Francis in Assisi. But amazingly, this limestone would provide the
210 material for researchers to more accurately date the movement of continents as well as
211 further their knowledge about the rate at which geologic change occurred.

212 The Scaglia Rossa is a pelagic sedimentary rock composed of 1-20% foraminifera and
213 5% clay in a coccolith matrix, deposited from the late Cretaceous to middle Eocene. Its
214 color ranges from brick red to pink and also grey, yellow and mixed white and pink. The
215 red and pink colors are due to the oxidation of the iron minerals limonite and hematite.
216 Because its deposition was undisturbed by erosional gaps, and it was filled with plankton
217 suited for dating and correlation over long distances, it carried a record of magnetic field
218 reversals which allowed researchers to obtain data on 100 Myr of geomagnetic polarity
219 stratigraphy (from c. 137- c. 23 Ma). This data was then used to affix dates on

220 reconstructed maps of the continental positions since the breakup of Pangea (Alvarez,
221 2009).

222 Some 65 Mya a giant meteorite hit the Earth, sending smoke, dust and a rare element,
223 iridium, into the atmosphere. The pollution blocked the sun which resulted in widespread
224 plant and animal death on Earth, including the dinosaurs. Remarkably, high levels of
225 iridium (c. 455 ppb in a meteorite vs. c.0.3 ppb in the Earth's crust), indicative of a
226 meteorite strike were found in the Scaglia Rossa strata dating to 65 Mya, the approximate
227 time of the extinction of the dinosaurs (Alvarez, 2008).

228 Another unusual landform with a unique stratigraphy found in the area are foreign rocks
229 of many different ages are called Ligurides. They were deposited in an ocean to the west
230 of Italy—one that no longer exists. They are composed of turbidites and pieces of ocean
231 crust dating from Triassic to Eocene that were displaced when the ocean was squeezed
232 shut. They have slid almost the entire way across the Italian Peninsula. As underlying
233 anticlinal ridges rose, the fragments would slide down the front toward the northeast.
234 Sometimes they are badly damaged and sometimes they are found in enormous blocks
235 (Alvarez, 2008).

236 In the area around Assisi, (Fig.4) Mt. Subasio, is an anticlinal fold of marine limestone
237 (pink, cream, gray) formed 10-15 Mya which dominates the landscape. The structural
238 setting is complex as it is cut in half by normal faults. Today, the eastern half of the
239 anticline stands while the western half dropped down to the valley below the town. The
240 area is seismically active. The Basilica of St. Francis of Assisi was constructed with Mt.
241 Subasio's pink Scaglia Rossa limestone (G. Lena,2014).

242 The Rieti basin (Figs. 5,10,11) is an intramontane depression of the Apennine chain and
243 home to a number of Franciscan monasteries. It is filled with continental plio-Quarternary
244 sediments made of conglomerates, sands, silts and travertine deposits that reach a
245 thickness of 400-500 meters. The origin and evolution of the Rieti basin is related to the
246 post-collisional extensional tectonics that have strongly affected this section of the
247 Apennine orogenic belt since the Pliocene. From the middle Pleistocene to Present along
248 the course of the Velino river numerous travertine thresholds accreted controlled by
249 alternating erosional and sedimentary phases (Mancini,2009).

250 The monastery at La Verna sits on Mt. Penna (Fig.6,17), a Miocene calarenite. It is highly
251 fractured and many caverns and clefts are etched into its surface. Boulders and scree
252 surround the base of the mountain. It rests on Cretaceous successions belonging to the
253 eastern Ligurian Units (Sillano Formation, Early Cretaceous) (Brogi, A., 2010).

254 As to the lithologic commentary on the art works, here are the types of deposits which
255 can be seen aboveground in the referenced areas: travertine, conglomerates, sands, silts,
256 dolomite, limestone, fluvio-lacustrine deposits, turbidites, carbonates, calcareous tufa,
257 evaporates, anhydrites, dolostones, marls, sandstone, (basement crystalline and volcanic

258 rocks which cannot be seen, have been left out). The oldest above ground deposits date
259 to the Triassic (252-201 Mya) (Carrara, 2004).

260 Comments on the strata will be categorized based on color, form and congruity with the
261 known geologic conditions in the area since the exact lithology in a Giotto work cannot be
262 determined with certainty.

263 For scenes depicting events in the region of the Holy Land, the rocks Giotto portrays are
264 devoid of vegetation reflective of the desert environment, all the while showing bedding
265 planes, erosional features and other realistic detail.

266 The following works by Giotto are a small sampling of his extraordinary output. They were
267 chosen because of his inclusion of geologic formations and natural elements.

1.5 Nativity

269 Francis staged the first living Nativity scene or *presepe* on Christmas in 1223 in a
270 limestone grotto at his monastery at Greccio (Fig.7). Interestingly, Francis had to obtain
271 papal permission to use an ox and an ass in the manger scene to avoid the charge of
272 novelty. Once approved, he invited the local townspeople, along with their animals, to
273 participate in a recreation of the holy event. He situated the participants, including
274 livestock, in the grotto and then placed a newborn in a manger cushioned with hay. After,
275 Francis stepped forward and lead a celebratory mass. The altar was a block of limestone,
276 still visible today. This brought the message of Jesus' birth down to Earth so that the
277 lowliest person could identify with the humble manner in which He was born.

278 If we look at a Byzantine representation of the Nativity (first part of the 14th c. (Fig.8)) we
279 can see Jesus' birth depicted in a cavern in a landscape complete with rocks, mountains
280 and trees. The Byzantine style, lacking perspective and scale, portrayed the figures and
281 landscape elements one-dimensionally, configured in a single plane (Dall'Asta,2012). In
282 religious art, this effectively created a psychological distance between the sacred events
283 and the viewer, evoking a reverential experience.

284 Giotto revolutionized art by taking Byzantine iconography and humanizing it (Fig.9).
285 Following Francis' lead, the Nativity thus became a natural event. Using elementary
286 perspective techniques, he was able to compose a sacred scene that appeared similar to
287 a person's daily life. In this way, the viewer had a direct experience with the miraculous,
288 allowing him to internalize the supernatural event and ultimately transfigure his human
289 consciousness into a vessel for the divine (Panofsky,1997).

290 Giotto also revolutionized the depiction of natural elements by including them as vital to
291 the composition, and also applying the same techniques-- perspective, shading, etc. on
292 them as he used on his figures. This rendered the scene realistic and the location was
293 often identifiable to the locals. In his portrayal of the Nativity he reproduced the geology
294 of the area surrounding the monastery at Greccio (Fig.10,11) which consists of carbonate
295 units of the Sabina Sequence (Meso-Cenozoic) (Carrara,2004) (Falcetti,2014).

He depicted a limestone ledge and added a rudimentary wooden roof for shelter. The limestone strata in the background are upthrust as shown by the vertical relief. These blocks, formed by the dynamic movement of the earth, now act as a sheltering backdrop for the manger holding the newborn. Angels also hover overhead to protect, pray and rejoice at the miraculous event. The ox and donkey on the left are farm animals, vital to the sustenance of the people. The sheep, goats and their shepherds were also common to the area. Today, going to the monastery at Greccio, (Fig.10) one can see the limestone cliffs, crevasses as well as the original grotto that inspired St. Francis.

In describing the Nativity, we are told that Mary and Joseph embarked on a journey, the night was cold and starry, there was no room in an inn nor help with the birth. The lowly manger was filled with hay and animals were settling in for the night. Here, we see that Giotto continues the theme of Jesus' birth in a limestone landscape (Fig.12). The upthrust block in the background provides shelter for the newborn set upon an altar-like formation of the bedrock in the foreground. And so, Jesus was born without fanfare as people went about their daily tasks. He did not stop the world, rather He changed its orientation and sensibility. Men continued to eat, talk and work, live and die, yet the birth of Jesus changed the intrinsic purpose of their actions and their lives. Placing Jesus in a manger, the locus where animals were fed, let us know that He would provide us with food as well (his body). The gospel of St. John 1:9 tells us: there came into the world the true light (external light) which illuminates every man. Meaning that with the birth of Jesus, divine light appeared on Earth and was the vehicle used to communicate the gift of divine life. In the story of Creation, the contrast between darkness and light was used as a metaphor. Now, in the mystery of the Nativity it returned, and was transfigured into a more intimate form (might be considered internal light) where God enters into the lives of men to create a second definitive creation. John 8:12 says "I am the light of the world, he who follows me does not walk in darkness but will have the light of his life." Giotto deftly incorporated light into his scenes to illustrate gospel teachings as well as well as miraculous events.

Another revolution in the portrayal of the Nativity was the change, in the 14th century, from the use of a cavern, to a "inn" (*kataluma*) as described in the Gospel of Luke. From that, the location was often a "diversorium" which might be an inn, a cabin (*capanna)*, or a hut with a canopy (*tettoia*) which were common in medieval cities (Dall'Asta,2012). These were public places where people came to rest and talk. These became the new churches, humble and unpretentious, according to the reform principles of the Franciscans who longed to return to a simple evangelization.

In this fresco, we pass from a desert, an isolated locale, to an urban setting (Fig.13). The abandonment of the desert and the grotto has a precise theological justification. By placing Jesus' birth in a city, not in the wilderness, the mystery of his divine nature would not be hidden from the people. He is portrayed as being born in a town, near a market, in an open, populated place where his nature can be seen by all.

The baby is often placed in the foreground on the earth, underlining his human character, propped on a bale of hay-- an illusion to the eucharistic bread, or on a sheet--evocative

of the shroud. In this manner, if the faithful looked down, they would have understood the humility of the divine birth. From an etymological standpoint, the word "humble" can be taken to mean "attached/close to the ground" (in Latin, *humus*).

1.6 Preaching to the Birds

In Byzantine art, the background was usually gold, a glorious, expensive color which invoked a sense of awe of the Divine and, as a result, kept the viewer at a reverential distance (Dall'Asta,2012). As a color, it was flat which did not draw the viewer into the scene. Giotto's treatment of this event (Fig.14) is very interesting because of his use of a gold background. The gold finish is textured and shaded and the dark foreground cuts a horizontal band, imparting depth and three dimensionality. He then places the tree in a manner in which it is growing out of the picture. St. Francis is preaching to birds who are walking and flying toward him, seemingly enraptured by his words. Due to the use of color, shading and perspective, Giotto created a work that had volume and movement. The tree is swaying in the wind, the birds are flying and walking and the friar behind St. Francis is in a different plane, giving the whole picture a sense of depth and dynamism. The warm colors invoke an autumn day with an orange-gold sun illuminating the background. While the use of earth tones and touches of dark gray-greens give the work a cohesiveness, warmth and intimacy. One wants to watch, an experience we have all had while viewing flocks of birds, yet we want to be still and quiet so as to not disturb them lest they fly away. In this manner, Giotto works his magic, allowing us to feel the peace and mystical nature of God's Earth and His creations by presenting them in a simple setting that is reminiscent of our everyday life.

An incident illustrating Francis' benevolent attitude towards nature is recounted in the *Fioretti di San Francesco* (The Little Flowers of St. Francis), a collection of legends and folklore that was compiled after his death. One day, while Francis was traveling with some companions, they happened upon a place in the road where birds filled the trees. He told his companions to "wait for me while I go to preach to my sisters the birds." The birds surrounded him, intrigued by the power of his voice, and not one of them flew away.

1.7 The Flight into Egypt

The Gospel of Matthew 2:13-23 recounts that after the visit of the Magi to the newborn child, an angel appeared to Joseph in a dream and told him to flee to Egypt with Mary and Jesus, as King Herod would seek to kill the child. In this scene, Giotto portrays an arid landscape (Fig.15). The mountains are sparsely vegetated and the desert through which they are traveling is inhospitable. It is an arduous journey with the donkey making its way along a narrow path with a steep precipice in the foreground. Joseph leads the way with an angel, most likely the one which appeared to him in the dream, guiding and protecting them on their way. Mary and the child sit upright, with great dignity as they endure the harsh traveling conditions. Giotto chooses a background of gray and blue to impart the sensation of a rocky, barren landscape where even the few trees must struggle to survive. He pays attention to the rock strata and bedding planes so that the formations

377 would appear close to those we see in nature. The dark blue sky and impending darkness
378 causes a sense of preoccupation for the welfare of the family. Were they traveling by
379 night to avoid detection or avoid the harsh sun? This is a mystery. Where will they rest?
380 There are no buildings or indications they are close to a village or city. So here, Giotto
381 presents a barren, dark, uninviting environment that would have been unfamiliar to the
382 Italians living in the florid Italian countryside. Yet, they would understand the hardship
383 involved for a mother and newborn to undertake this journey on a donkey. The vast
384 unknown terrain, with no water or vegetation to sustain them, leaves the viewer
385 sympathizing with the Holy Family and respecting the sacrifice they made for our ultimate
386 salvation.

1.8 The Dream of Joachim

388 This touching scene shows St. Joachim, husband of St. Ann and father of the Blessed
389 Virgin Mary, in exile in the wilderness (Fig.16). The landscape, colors, and posture of St.
390 Joachim convey a profound sense of despair. St. Joachim and St. Ann had reached
391 advanced ages without having a child. This was considered an indication of God's wrath.
392 Joachim went to the temple to make a sacrifice, which was rejected, and he was then
393 expelled by the rabbis. He went into exile in the mountains leaving behind his wife, Ann.
394 As we can see, Giotto places him in a hunched-over position with his head resting on his
395 knees. He is desperate, inconsolable. He sits directly on the ground, is he so weak or
396 defeated that he no longer can or will get up? The landscape is stark and a dark mountain
397 with no vegetation rises menacingly in the background. The carbonate rocks in the fore
398 and middle ground are lighter, reflecting their natural color, but arid, save for a very few
399 trees. The only people in view are the shepherds who frequented the mountains with their
400 flocks. The small cabin is made of blocks of limestone likely mined from the local area.
401 Perhaps it was the "*refugio*" or cabin of the shepherd who used it at night. One of the
402 sheep appears to be entering a grike (solution fissure). Giotto portrays the natural
403 landscape here as barren, a metaphor for the fruitless matrimony of Joachim and Ann.
404 He does a marvelous job depicting the nearly vertical bedding planes of the dark brown
405 formation, perhaps a bedded sandstone, in the distant background. Geologically, the
406 beds were originally laid down flat, and with subsequent deformation and movement they
407 were thrust upward into their nearly vertical configuration. Giotto depicts the carbonates
408 in the foreground as they appear in nature, blocky, with cracks and crevasses and, where
409 it has been eroded by wind or rain, has softer edges. Giotto creates a masterful geologic
410 environment, paying careful attention to the physical characteristics of the different types
411 of rock. What hope can there be in such an environment where there is no sign of fertility,
412 no lush green plants, no water—nothing. There is something however, the angel. It is
413 bringing word to Joachim that Ann is with child and she will be blessed. Joachim's world
414 will change with this message and our world will be changed as well.

1.9 St. Francis Receiving the Stigmata

416 The grotto of the monastery at La Verna was the place at which St. Francis received the
417 stigmata of Christ in 1224. La Verna, where today, pilgrims still visit to pray and meditate

is located on Mt. Penna (Fig.6) in the Apennine ridge connecting Casentino and Valtiberina. In ancient times, people couldn't explain how this mount, a mass of limestone, came to be, so the legend was born that it (Mount Alvernia in Latin), geographically known as Mt. Penna was created by a strong earthquake occurring when Jesus died on the cross. Its geological origins are so complex that even today, scholars are still trying to decipher it. However, research (Brogi, et. al, 2010) indicates that Mt. Penna (Fig.17) is composed of Miocene calcarenite resting Cretaceous successions belonging to the eastern Ligurian Units (Sillano Formation, Early Cretaceous)

In this image of solitary mystical experience (Fig. 18), Giotto portrays Francis on a block of limestone which has been weathered and uplifted as seen by its nearly vertical relief. A cleft in the side of the cliff, common to calcareous deposits, has opened. Giotto uses this rock, which has been sliced open, to imitate the wounds in St. Francis' hands and feet. The church in the foreground is made of the gray limestone found in the area and commonly used for construction. To the left of the church grikes (solution fissures) and clints (limestone separated from adjacent sections by solution fissures) are starting to form. Behind the kneeling figure is the cave where, in one account, he struggled nightly with demons. Above the cave perches the falcon which woke him for his vigils, and whose hovering flutter was an omen of the heights of contemplation to which Francis would soar. Flora and fauna are sparse and the sky is a deep gray black forcing us to pay attention to the miracle that is playing out on this mountainside. The Franciscans used this location and divine occurrence to demonstrate that mountains were vital in the sacred ritual, thus promulgating the idea that they would provide a nearness to God and a source of divine inspiration (Schama,1995).

An excerpt from the anthology "*Fioretti di San Francesco"* (The Little Flowers of St. Francis), describes this miracle:

"considering the form of the mountain and marveling at the
exceeding great clefts and caverns in the mighty rocks, he betook
himself to prayer and it was revealed to him that those clefts…
had been miraculously made at the hour of the Passion of Christ
when, according to the gospel, the rocks were rent asunder."

1.10 St. Francis Gives His Mantle to a Poor Man

In this scene, Francis demonstrates his commitment to refuting worldly goods by giving his mantle to a poor man (Fig.19). He has abandoned his fine clothing and is now dressed in the simple sackcloth emblematic of the congregation of friars. This is an unwitnessed and spontaneous act which takes place in a rural setting. While art historians claim the town on the hill is Assisi, this would not be accurate as Assisi sits on the western edge of Monte Subasio, anticlinal fold formed 10-15 Mya above the thrust ramps and cut in half by normal faults as the extensional front passed through in the last few million years. And so, the Monte Subasio we see today is a "half anticline" with the eastern half still standing and western half dropped down to the valley to the west of the town (Alvarez,2008). The actual site may be another location (there are many) or a montage used for dramatic

effect as Francis is placed at the midpoint, between two hills, one with a town and the other with a monastery. He leaves one behind and moves unknowingly toward the other. Giotto uses perspective and scale to depict the town realistically in the distance, complete with the walls which surround it. Remnants of medieval walls such as these, constructed with local material, often limestone, can still be seen today. The towns were historically located on high ground for security. The finely detailed terrain is evocative of the countryside one can see today in central Italy. The rock formations are most likely limestone due to the color, blocky form, faults, grikes and clints. Enormous sections of strata were overturned and displaced as a result of thrust-block mountain building and continuous seismic activity in the region since Roman times (Guidoboni,2012). The gorges and crevices still visible in many areas today are for the most part unnamed and are best seen untouched in the many national parks, but one, the Bottaccione Gorge near Gubbio, is a mecca for geologists looking at the famous K/T boundary in the Scaglia Rossa limestone.

It is said that Francis walked from one village to another, where he would preach. Giotto places him on a solitary path out of town. In this way, out of sight of anyone, he practiced his charity—anonymously and in the midst of nature. The colors Giotto uses are characteristic of limestone, ranging from milky white to ivory to light gray and pink. The towns would have been constructed with blocks of local calcareous rock so the delicate pastels which characterize the buildings and walls are the actual color of the indigenous rock. In fact, many of the buildings in Giotto's frescoes are pink. The trees hang precariously on the slopes as they endeavor to insert their roots in crevasses and cracks. The misty blue sky is common to the area, where frequent rainfall and clouds add to the mystique of the atmosphere. A scene like this would resonate with any viewer as they would understand the landscape and could recognize the local cities with their houses, churches and towers. They could see familiar mountain paths and remember their own difficult journeys, be them psychological, spiritual or corporeal. And so, through Francis' example, and ultimately through their own actions, seen or unseen, they could become saints as well.

1.11 The Legend of St. Francis: Miracle of the Spring

St. Francis, retiring to pray in the wilderness during high summer became ill and was forced to go by donkey (Fig.20). When the farmer who owned the animal begged for water, Francis took pity on him and, after praying, struck a rock and water came bubbling out of the earth. Here, Giotto portrays the landscape in the foreground and middle of the picture with wave-like patterns formed by the erosion of stratified limestone, such as the Maiolica limestone found in many parts of Umbria (Galdenzi,2013). In the background, large blocks have been displaced and turned upright when thrust faults sliced up through the earth. The textures bedding planes and erosional patterns are realistic. In the foreground St. Francis prays on what appears to be and inclined calcareous sinter terrace. In the foreground we see a crevasse which was formed during the ongoing seismic or thrust-block mountain building activity in the area. In the background we see a

dark area between the two rock formations which may be a fault. Limestone is porous and often springs will gush forth from the interior of the earth. The ground has been fractured and deformed and many faults have caused displacement of strata as well as fissures and crevasses. Interestingly, the Italian Secretary of Transportation, Riccardo Nencini, advanced an idea that the actual location of this spring is the cascade of the Rovigo torrent in Firenzuola. While this is not supported by geologic data, it is a tribute to the power of Giotto's imagery, in that, after 700 years, people are attempting to identify the landscapes he depicted.

1.12 The Enduring Legacy of St. Francis and Giotto

The frescoes, altar panels and paintings reflecting the new naturalistic style also provided visual accompaniment to the popular preaching approach practiced by St. Francis-- not in Latin, but in the spoken language (Umbrian form of Italian). Together, the visual and the audible messages centered on the mystery of the Incarnation and on the need for repentance. In fact, the power of the visual representation of nature was much more powerful than the written word, as most people were illiterate and texts available for study were for the most part, ancient or ecclesiastical. Aristotle, Pliny and others formed the basis of natural philosophy and their ideas had not been altered or challenged in 1,500 years (Grant, 2010). With the arrival of St. Francis and Giotto however, a shift in thinking resulted in massive changes in many disciplines, and nature was one of them (Schama, 1995). When texts on nature started to be published in the Renaissance, the ideas they set forth were very late in arriving, for the ecological and natural history ideas of St. Francis as represented artistically by Giotto had already been absorbed into the psyche of the common man for over 200 years.

Some 750 years after the saint's death, on 29 November 1979, Pope John Paul II declared Saint Francis the Patron Saint of Ecology. Successive Popes continued to use St. Francis as a model in their public comments over the years:

"…not to behave like dissident predators where nature is concerned, but to assume responsibility for it, taking all care so that everything stays healthy and integrated, so as to offer a welcoming and friendly environment even to those who succeed us."

"As a friend of the poor who was loved by God's creatures, Saint Francis invited all of creation – animals, plants, natural forces, even Brother Sun and Sister Moon – to give honor and praise to the Lord. The poor man of Assisi gives us striking witness that when we are at peace with God we are better able to devote ourselves to building up that peace with all creation which is inseparable from peace among all peoples."

 "It is my hope that the inspiration of Saint Francis will help us to keep ever alive a sense of 'fraternity' with all those good and beautiful things which Almighty God has created."

"St. Francis teaches us that, the world of God and the world of nature are one."

1.13 Conclusion

St. Francis and Giotto, two revolutionary figures who never knew each other, were linked by history and art. Unbeknownst to them, their legacy would ultimately change Western piety, art and natural history. Much of today's ecological movement has embraced the tenets espoused by St. Francis. Giotto not only immortalized Francis' idea of the sacredness of nature by carefully placing and configuring geological elements realistically in his frescoes, he provided a lasting visual record, which allows modern researchers a basis for further study. Not only can they identify the landforms of central Italy, one of the most complicated areas in the world, they know that Giotto's pastel colored buildings were not flights of fancy but duplicated the colors of the indigenous pink, grey and ivory limestone actually used in medieval construction. Amazingly, the use of the pink Scaglia Rossa limestone to build the Basilica of St. Francis would end up being the key to unlocking many mysteries in the history of geology. So while researchers continue to study the outcrops and mountains on which St. Francis build his monasteries, they will also learn that these outcrops were, and still are, miraculously sacred sites. And so, central Italy seems to be a geologist's paradise, where one can participate in the realm of art and religion by looking at Giotto's frescoes and unlock the Earth's mysteries while walking in the footsteps of St. Francis.

Definitions

Anticline-In structural geology, an anticline is a type of fold that is an arch-like shape and has its oldest beds at its core.

Calcarenite- A type of limestone that is composed predominantly, more than 50 percent, of detrital (transported) sand-size (0.0625 to 2 mm in diameter), carbonate grains. The grains consist of sand-size grains of either corals, shells, pellets, fragments of older limestones and dolomites, other carbonate grains, or some combination of these. Calcarenite is the carbonate equivalent of a sandstone.

Coccoliths- Are individual plates of calcium carbonate formed by coccolithophores (single-celled algae such as *Emiliania huxleyi*) which are arranged around them in a *coccosphere.*

Conglomerate-Is a coarse-grained clastic sedimentary rock that is composed of a substantial fraction of rounded to subangular gravel-sized clasts, e.g., granules, pebbles, cobbles and boulders, larger than 2 mm. in diameter.

Fault- Is a planar fracture or discontinuity in a volume of rock across which there has been significant displacement as a result of rock-mass movement.

Fault blocks- Are very large blocks of rock, sometimes hundreds of kilometers in extent, created by tectonic and localized stresses in the Earth's crust.

Foraminifera-Informally called "forams", are members of a phylum or class of amoeboid protists characterized by streaming granular ectoplasm for catching food and other uses; and commonly an external shell (called a "test") of diverse forms and materials.

584

585 *Marl or marlstone*-Is a calcium carbonate or lime-rich mud or mudstone which contains
586 variable amounts of clays and silt. The dominant carbonate mineral in most marls
587 is calcite, but other carbonate minerals such as aragonite, dolomite, and siderite may be
588 present.

589

590 *Turbidite*- Is the geologic deposit of a turbidity current, which is a type of sediment gravity
591 flow responsible for distributing vast amounts of clastic sediment into the deep ocean.

592

593 *Orogeny*- Is the primary mechanism by which mountains are built on continents.

594

595 *Scree*-Is a collection of broken rock fragments at the base of crags, mountain cliffs,
596 volcanoes or valley shoulders that has accumulated through periodic rockfall from
597 adjacent cliff faces.

598

599 *Tectonics*-Is the process that controls the structure and properties of the Earth's crust and
600 its evolution through time. In particular, it describes the processes of mountain building.

601

602 *Thrust fault*- is a break in the Earth's crust, across which older rocks are pushed above
603 younger rocks.

604

605 *Travertine*-Is a form of limestone deposited by mineral springs, especially hot springs.

606 Source: Wikipedia

References

608 Alvarez, Walter, *The Mountains of Saint Francis: Discovering the Geologic Events That
609 Shaped Our Earth*, W.W. Norton and Co. 2008.

610 Alvarez, Walter, *The historical record in the Scaglia limestone at Gubbio: magnetic
611 reversals and the Cretaceous-Tertiary mass extinction.* Sedimentology, 56, 137-148,
612 2009.

613 Anonymous, *I Fioretti di San Francesco* Il Novellino, Rizzoli, Milano, 1979.

614

615 Artz, Frederick B., *The Mind of the Middle Ages: An Historical Survey*
616 University of Chicago Press, 2014.

617

618 Sidney J. Blatt. *Continuity and Change in Art: The Development of Modes of
619 Representation.* In collaboration with Ethel S. Blatt. Hillsdale, N.J., and London: Lawrence
620 Erlbaum Associates, 1984.

621

622 Brogi, A., Fabbrini, L. *The Monte Penna thrust (southern Tuscany, Italy): Geometry and
623 kinematic of a collisional structure affecting the Tuscan Nappe during the Northern*

Apennines orogenic building. Italian Journal of Geosciences 129(1) 74-90, February 2010.

Cadden, Joan, *Science and Rhetoric in the Middle Ages: The Natural Philosophy of William of Conches,* Journal of the History of Ideas University of Pennsylvania Press Vol. 56, No. 1 (Jan., 1995), pp. 1-24

Carrara, C., Ferreli, I., et al. International Geological Congress Field Trip: *The Rieti Intermountain Basin and S. Francesco d'Assisi* c/o IGAG - CNR, Roma, Italy. Apat - Italian agency for Environmental Protection and Technical Services, Roma, 2004.

Chenu, Marie-Dominque, *Nature, Man and Society in the Twelfth Century,* Chicago UP, 1968. New edition edition (March 1983).

Crombie, A. C., *Science, Art and Nature in Medieval and Modern Thought*. Rio Grande, Ohio: Hambledon Press. 1996.

Dall'Asta, Andrea, *Nascere Il Natale nell'arte*, Edizioni San Paolo, Milano, 2012.

Edgerton, Samuel Y., *The Heritage of Giotto's Geometry Art and Science on the Eve of the Scientific Revolution*. Cornell University Press, Ithaca, 1993.

Edgerton, Samuel Y., *The Renaissance Rediscovery of Linear Perspective*. New York: Basic Books. 1975.

Falcetti s, Guerrieri I., et. al., *Field trip guide to the Rieti Plain and the Rieti town. Geological and hydrogeological aspects of a territory featured by historical and cultural heritage*. Mem. Descr. Carta Geol. d'It.102, pp. 73 – 86 fig. 15 Servizio Geologico d'Italia-ISPRA Roma, 2014.

French, Roger, and Cunningham, Andrew, *Before Science: The Invention of the Friars' Natural Philosophy*
Routledge (1996)

Fusarelli, Massimo ofm, *Guide to the Sanctuaries of the Rieti Valley*, B.N. Marconi, 1999.

Galdenzi, Sandro, *Sasso Pozzo Cave (Gagliole, Italy): Hydrology and Speleogenetic Evolution,* Alpine and Mediterranean Quaternary, 26 (1), pgs. 65-76, 2013.

Grant, E. (1996). *The Foundations of Modern Science in the Middle Ages: Their Religious, Institutional and Intellectual Contexts* (Cambridge Studies in the History of Science). Cambridge: Cambridge University Press. doi:10.1017/CBO9780511817908

Edward Grant. *The Nature of Natural Philosophy in the Late Middle Ages*. (Studies in Philosophy and the History of Philosophy, 52.), Washington, D.C.: Catholic University of America Press, 2010.

Hugh of St. Victor "*De Scripturis et Scriptoribus Sacris*" in Hugonis de S. Victore…Opera Omnia, 1 (of 3), Patrologis Latina Vol. 175 (J.P. Migne, 1854)

Lena, G., Barchi, M.R., Alvarez, W, et. al., *Mesostructural analysis of S-C fabrics in a shallow shear zone of the Umbria–Marche Apennines (Central Italy),* Geological Society, London, Special Publications, 409, 149-166, 19 November 2014

Mancini, Marco, Cavinato, Gian Paolo, *The Middle Valley of the Tiber River, Central Italy: Plio-Pleistocene Fluvial and Coastal Sedimentation, Extensional Tectonics and Volcanism*. Fluvial Sedimentology VII, pp. 373-396. 2009.

Moleta, Vincent, *From St. Francis to Giotto*, Franciscan Herald Press, Chicago, 1983.

Nessi, Silvestro, Inventario e regesti d' Archivio del Sacro Convento d'Assisi (Padua, 1991), 90 n. 223.

Panofsky, Erwin, P*erspective as Symbolic Form*, Zone Books, 1997.

Pizzorusso, Ann, *Tweeting da Vinci*, Da Vinci Press, New York, 2013.

Schama, Simon, *Landscape and Memory*, Knopf, New York, 1995

Zeri, Federico, *Giotto Compianto su Cristo morto*, Rizzoli, Milano, 1993.

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676 Fig. 1. Map showing selected Franciscan monasteries in Tuscany/Lazio/Umbria (in yellow) and walking paths from one to another.
677 Note that there are others in Italy which were not chosen as part of this study. Public domain Wiki Commons.
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681   Fig. 2. Pink streaked with white Scaglia Rossa limestone is a pelagic sedimentary rock with forams and clay in a coccolith matix dating
682   from the Late Cretaceous to middle Eocene. Mined from the Mt. Subasio quarry and used to construct the St. Francis basilica at
683   Assisi. Public domain Wiki Commons

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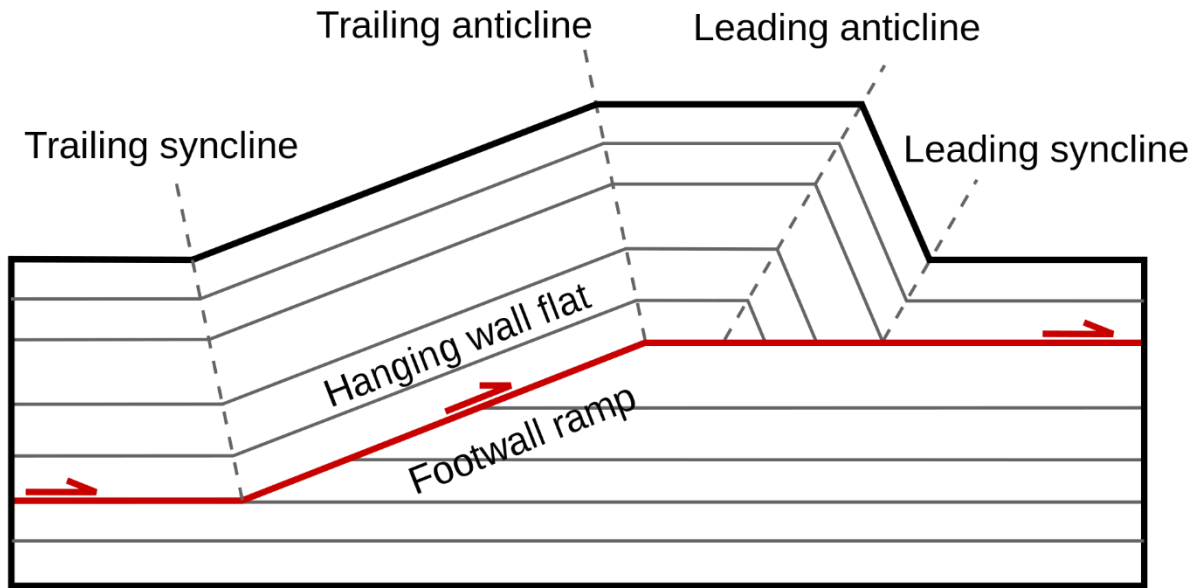
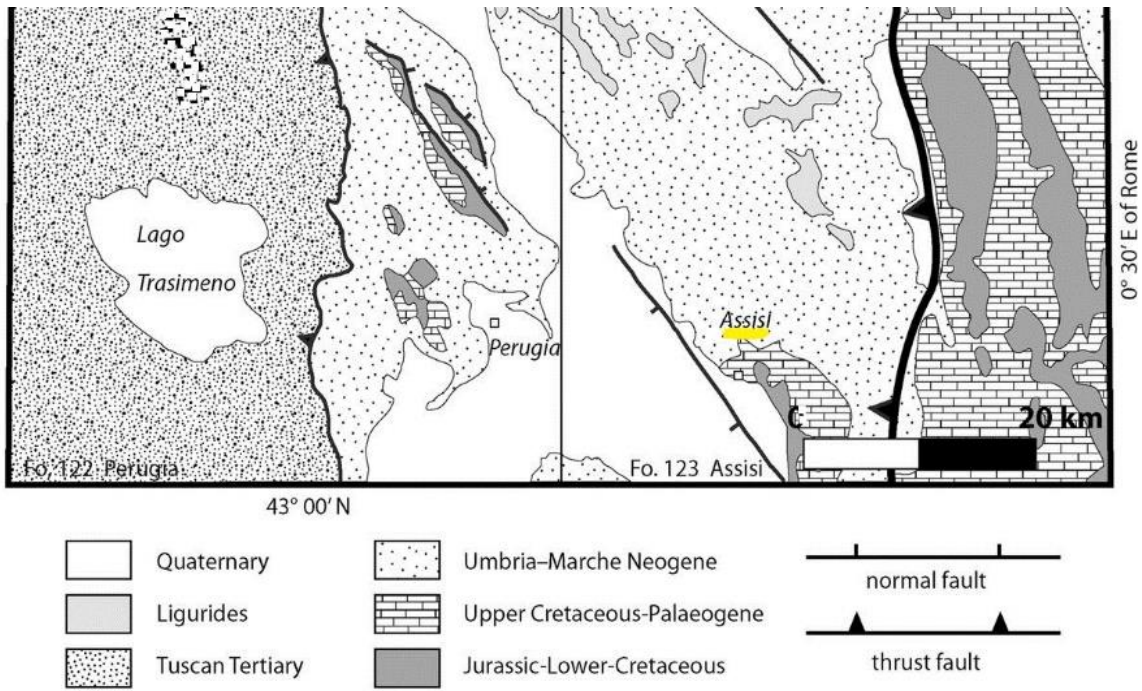

Fault-bend fold

Fig. 3. Diagram of the anticlinal fold mountains formed by compression. Wiki Commons.

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695 Fig. 4. Geologic map of the area around Assisi. After G. Lena, et al. Geological Society, London 409,
696 November 2014.

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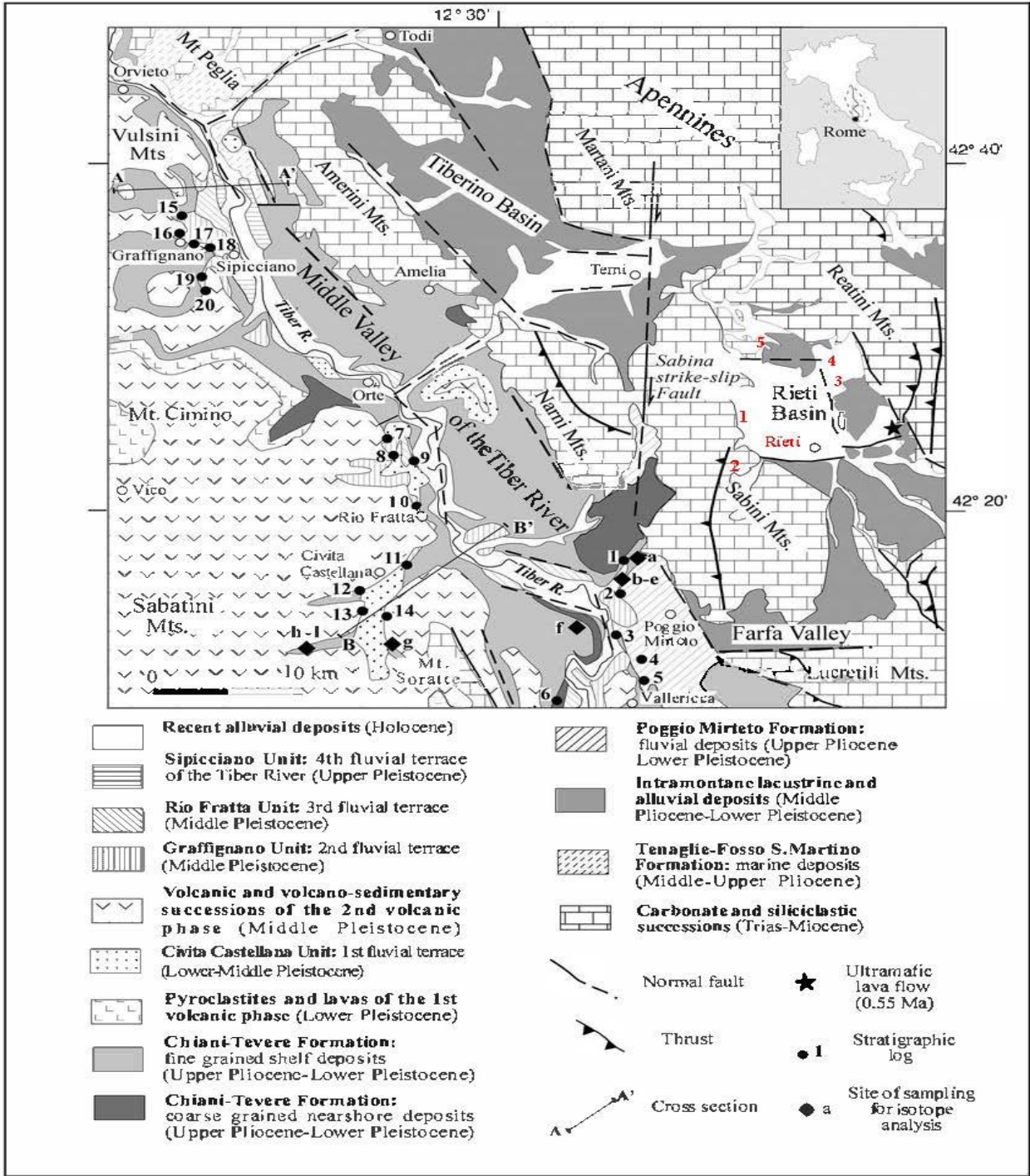
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705 Fig. 5. Franciscan monasteries (in Red) 1) Greccio 2) Santuario di Fonte Colombo 3) Santuario della
706 Foresta 4) Poggio Bustone 5) Labro. After Mancini, et. al. (2009).

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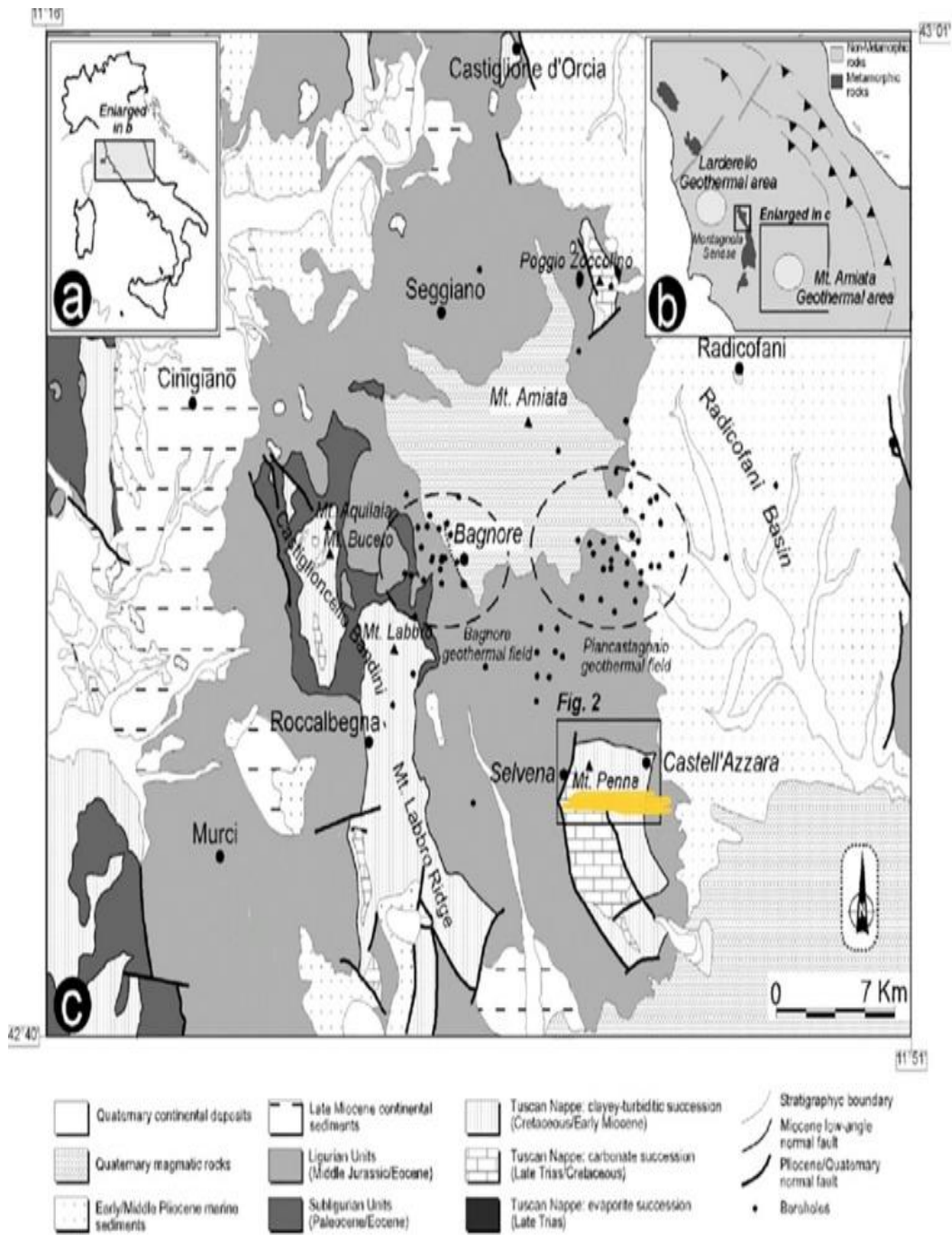
Fig. 6. The monastery at La Verna sits on Mt. Penna, a Miocene calarenite. It is highly fractured and
many caverns and clefts are etched into its surface. Boulders and scree surround the base of the
mountain. It rests on Cretaceous successions belonging to the eastern Ligurian Units (Sillano Formation,
Early Cretaceous). After Brogi, A., et. al. Italian Journal of Geosciences 129(1) 74-90, February 2010.

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720 Fig. 7. Limestone grotto at the monastery at Greccio, site of the first Nativity scene organized by Francis on Christmas in 1223. The
721 limestone outcrop was the original altar before another was placed above it when the Pope visited. The 14th century frescoes depict
722 the original Nativity scene. Photo by Ann C. Pizzorusso.

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728   Fig. 8. Nativity. Andrej Rublev. Note how the figures are one dimensional and the entire work lacks perspective. First half of 14th
729   century. Moscow, Tretjakov Gallery. Public domain Wiki Commons

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734   Fig. 9. Nativity. Giotto, c. 1303-c.1306 Scrovegni (Arena) Chapel, Padua, Italy. Public domain Wiki Commons

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737 Fig. 10. Greccio, view of the monastery, location of the first living Nativity scene organized by Francis in 1223. The monastery is
738 located along a thrust fault and is built on carbonate units of the Sabina Sequence (Meso-Cenozoic). See geologic map (Fig.5). Photo
739 by Ann C. Pizzorusso.

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741

742 Fig. 11. View from the monastery at Greccio, built on carbonates, looking out at the fluvio-lacustrine and fan deposits. Photo by Ann
743 C. Pizzorusso.

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748   Fig. 12. Giotto. Nativity. Lower Church, Assisi c. 1310. Public domain Wiki Commons

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752 Fig. 13. Giotto. Nativity scene. C. 1297-1300. St. Francis Upper Church Assisi. Note the change of locus from the outdoor manger to
753 an urban, interior, populated, public church. Public domain Wiki Commons

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761   Fig. 14. St. Francis Preaching to the Birds. Giotto. 1295-1300. Louvre. Public domain Wiki Commons

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766   Fig. 15. The Flight into Egypt. Giotto. 1304-1306. Scrovegni (Arena) Chapel, Padua, Italy. Public domain Wiki Commons

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769   Fig. 16. The Dream of Joachim, Giotto. 1304-06 Scrovegni (Arena) Chapel, Padua, Italy. Public domain Wiki Commons

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772 Fig. 17. The monastery at La Verna located on Mt. Penna composed of Miocene calcarenite. Public domani Wiki
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780 Fig. 18. St. Francis Receiving the Stigmata. Giotto. 1318. Bardi Chapel, Santa Croce Basilica, Florence, Italy. Public domain Wiki
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Fig. 19. St. Francis Gives His Mantle to a Poor Man. 1297-1299. Basilica of Saint Francis, Assisi, Italy. Public domain Wiki Commons

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791 Fig. 20. The Legend of St. Francis: Miracle of the Spring 1297-1300 Upper Church, Assisi. Note the realistic depiction of the wave-
792 like marks of erosion along the bedding planes of the stratified limestone. Public domain Wiki Commons

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