

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

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

49
50 My fascination with St. Francis developed because of his revolutionary ideas regarding
51 ecology, but I soon learned that without the illustration of his ideas in frescoes by Giotto,
52 he might not have had such a powerful and lasting impact. The analysis of Giotto's
53 frescoes from a geological standpoint was a challenge, as St. Francis' monasteries were
54 located in central Italy, a region that has some of the most complex and still unexplained
55 geology in the world. Yet, it was precisely this geology that made Giotto's frescoes full of
56 geomorphological wonder. He integrated his figures into this dramatically disordered
57 landscape, forming a compelling composition for any viewer. The scenes portrayed in the
58 frescoes have survived 700 years, allowing modern geologists the opportunity to study
59 and compare them to formations visible today. In fact, discoveries in the pink Scaglia
60 Rossa limestone ended up being the key to solving some of the most perplexing questions
61 in historical geology.

62
63 In order to appreciate the revolutionary ideas of St. Francis and Giotto, a background on
64 the medieval ideas pertaining to nature will be discussed. A select number of frescoes
65 will be analyzed geologically, with attendant historical information explaining the scene.
66 Geologic maps which can be used as references for the cited locations are also included.

67

68 **1.1 The Idea of Nature in the Middle Ages**

69
70 In the Middle Ages, the practice of linking natural phenomena to divine or satanic forces
71 was the norm (Artz,2014). Since nature's behavior could not be predicted or controlled,
72 medieval man lived in a constant state of awareness of its capriciousness. In order to
73 alleviate stress, a method of spiritual interpretation called "anagoge" was devised by
74 medieval theologians, notably Hugh of St. Victor (c.1096-1141), to explain natural
75 occurrences. This meant that one had to search for the of meaning God's messages in
76 nature through the complex and oftentimes arbitrary symbolism He chose to use
77 (Cadden,1995). It was thought that by deciphering and diffusing malefic symbols one
78 could avoid disaster or, in the case of auspicious portents, obtain a fortuitous outcome.
79 The search for meaning in nature was much more important than the search for "how
80 nature works" as mechanisms were not valued (Chenu,1983). After all, God was in charge
81 of everything and what he was doing "behind the scenes" didn't matter. As a result, men
82 tried to become more empathetic and more closely aligned to nature to understand God.

83

84 **1.2 St. Francis**

85
86 In the early 1200's, a young man from Assisi named Giovanni di Pietro di Bernardone,
87 but known to us as Francis, gained a following for his revolutionary ideas pertaining to a
88 sympathetic view of nature. Francis lived in Umbria, a region of Italy which is green, fertile
89 and infused with a palpable spirituality. He was born into a well-to-do family of cloth
90 merchants. As a young man, he renounced his own material wealth, even taking the
91 position that the Church do the same. He walked to towns and villages, espousing a
92 simple way of life and encouraging a reverential attitude toward the natural world, for he

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

101
102 Soon he attracted a group of followers which were organized into many religious orders
103 for both men and women. He became so influential that the Pope had to acknowledge
104 him and allow his orders (Order of Friars Minor, the women's Order of Saint Clare, the
105 Third Order of Saint Francis and the Custody of the Holy Land) to be officially recognized
106 by the Church.

107
108 Francis was so venerated that Pope Gregory IX canonized him in 1228, only two years
109 after his death and ordered a basilica be constructed in Assisi. It was built with indigenous
110 pink Scaglia Rossa limestone (Fig. 2) and completed in 1253. Astonishingly, this Scaglia
111 Rossa limestone, depicted in Giotto’s frescoes, held the key which would revolutionize
112 the history of geology.

113 114 **1.3 Giotto**

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

122
123 Giotto’s works were so revolutionary that today he is considered the founder of
124 Renaissance art (Moleta,1983). But the seeds of this dramatic stylistic transformation
125 were planted by Cimabue, who worked at Assisi during the Pontificate (1288-1292) of
126 Nicolas IV, the first Franciscan Pope. Cimabue broke from the rigidness of Byzantine art
127 where figures were rendered flat and one dimensional (Dall’Asta,2012). Instead, he made
128 them more realistic by using proportions and shading for volume.

129 Giotto followed Cimabue’s lead in changing the flat figures of the Byzantine art form,
130 conducive to contemplation, to a more relaxed style by showing man in a natural setting
131 (Dall’Asta,2012). He observed the landscape and sought to portray its beauty and order.
132 He used painting techniques to depict figures more solidly, so that they would appear
133 three dimensional and thus, created the illusion that they were moving through a
134 landscape within the picture. Giotto integrated sacred images into the Earthly landscape,
135 separating them definitively from their abstract representation in Byzantine art. By
136 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 (Figs. 4, 5,6).

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 et al.,
197 2014). They extend from southwest to northeast. This orderly sequence occurs when
198 material deposited while building the anticline becomes too large for continued
199 displacement and the thrust fault slices a new ramp along weaker strata. The process
200 continues, with a set of parallel folds visible at the surface forming "propagating fold-thrust
201 belts" which slice 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 et al., 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-Quaternary
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 et al., 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, et al., 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 et al., 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.

268 **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 et al., 2004) (Falcetti et al.,
296 2014).

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

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

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

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

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

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

341 **1.6 Preaching to the Birds**

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

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

366 **1.7 The Flight into Egypt**

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

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

388 **1.8 The Dream of Joachim**

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

416 **1.9 St. Francis Receiving the Stigmata**

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

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

427
428 In this image of solitary mystical experience (Fig. 18), Giotto portrays Francis on a block
429 of limestone which has been weathered and uplifted as seen by its nearly vertical relief.
430 A cleft in the side of the cliff, common to calcareous deposits, has opened. Giotto uses
431 this rock, which has been sliced open, to imitate the wounds in St. Francis' hands and
432 feet. The church in the foreground is made of the gray limestone found in the area and
433 commonly used for construction. To the left of the church grikes (solution fissures) and
434 clints (limestone separated from adjacent sections by solution fissures) are starting to
435 form. Behind the kneeling figure is the cave where, in one account, he struggled nightly
436 with demons. Above the cave perches the falcon which woke him for his vigils, and whose
437 hovering flutter was an omen of the heights of contemplation to which Francis would soar.
438 Flora and fauna are sparse and the sky is a deep gray black forcing us to pay attention
439 to the miracle that is playing out on this mountainside. The Franciscans used this location
440 and divine occurrence to demonstrate that mountains were vital in the sacred ritual, thus
441 promulgating the idea that they would provide a nearness to God and a source of divine
442 inspiration (Schama,1995).

443
444 An excerpt from the anthology "*Fioretti di San Francesco*" (The Little Flowers of St.
445 Francis, anonymous medieval manuscript), describes this miracle:

446
447 "considering the form of the mountain and marveling at the
448 exceeding great clefts and caverns in the mighty rocks, he betook
449 himself to prayer and it was revealed to him that those clefts...
450 had been miraculously made at the hour of the Passion of Christ
451 when, according to the gospel, the rocks were rent asunder."

452 453 **1.10 St. Francis Gives His Mantle to a Poor Man**

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

464 effect as Francis is placed at the midpoint, between two hills, one with a town and the
465 other with a monastery. He leaves one behind and moves unknowingly toward the other.
466 Giotto uses perspective and scale to depict the town realistically in the distance, complete
467 with the walls which surround it. Remnants of medieval walls such as these, constructed
468 with local material, often limestone, can still be seen today. The towns were historically
469 located on high ground for security. The finely detailed terrain is evocative of the
470 countryside one can see today in central Italy. The rock formations are most likely
471 limestone due to the color, blocky form, faults, grikes and clints. Enormous sections of
472 strata were overturned and displaced as a result of thrust-block mountain building and
473 continuous seismic activity in the region since Roman times (Guidoboni & Ferrari, 2000).
474 The gorges and crevices still visible in many areas today are for the most part unnamed
475 and are best seen untouched in the many national parks, but one, the Bottaccione Gorge
476 near Gubbio, is a mecca for geologists looking at the famous K/T boundary in the Scaglia
477 Rossa limestone.

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

493 **1.11 The Legend of St. Francis: Miracle of the Spring**

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

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

513 **1.12 The Enduring Legacy of St. Francis and Giotto**

514 The frescoes, altar panels and paintings reflecting the new naturalistic style also provided
515 visual accompaniment to the popular preaching approach practiced by St. Francis-- not
516 in Latin, but in the spoken language (Umbrian form of Italian). Together, the visual and
517 the audible messages centered on the mystery of the Incarnation and on the need for
518 repentance. In fact, the power of the visual representation of nature was much more
519 powerful than the written word, as most people were illiterate and texts available for study
520 were for the most part, ancient or ecclesiastical. Aristotle, Pliny and others formed the
521 basis of natural philosophy and their ideas had not been altered or challenged in 1,500
522 years (Grant, 2010). With the arrival of St. Francis and Giotto however, a shift in thinking
523 resulted in massive changes in many disciplines, and nature was one of them (Schama,
524 1995). When texts on nature started to be published in the Renaissance, the ideas they
525 set forth were very late in arriving, for the ecological and natural history ideas of St.
526 Francis as represented artistically by Giotto had already been absorbed into the psyche
527 of the common man for over 200 years.

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

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

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

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

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

542 **1.13 Conclusion**

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

560 **Definitions**

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

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

568
569 Coccoliths- Are individual plates of calcium carbonate formed by coccolithophores
570 (single-celled algae such as *Emiliana huxleyi*) which are arranged around them in
571 a coccosphere.

572
573 Conglomerate-Is a coarse-grained clastic sedimentary rock that is composed of a
574 substantial fraction of rounded to subangular gravel-sized clasts, e.g., granules, pebbles,
575 cobbles and boulders, larger than 2 mm. in diameter.

576
577 Fault- Is a planar fracture or discontinuity in a volume of rock across which there has
578 been significant displacement as a result of rock-mass movement.

579
580 Fault blocks- Are very large blocks of rock, sometimes hundreds of kilometers in extent,
581 created by tectonic and localized stresses in the Earth's crust.

582

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

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

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

594
595 Orogeny- Is the primary mechanism by which mountains are built on continents.

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

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

604
605 Thrust fault- Is a break in the Earth's crust, across which older rocks are pushed above
606 younger rocks.

607
608 Travertine- Is a form of limestone deposited by mineral springs, especially hot springs.

609 Source: Wikipedia

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Fig. 1. Map showing selected Franciscan monasteries in Tuscany/Lazio/Umbria (in yellow) and walking paths from one to another. Note that there are others in Italy which were not chosen as part of this study. Public domain Wiki Commons.



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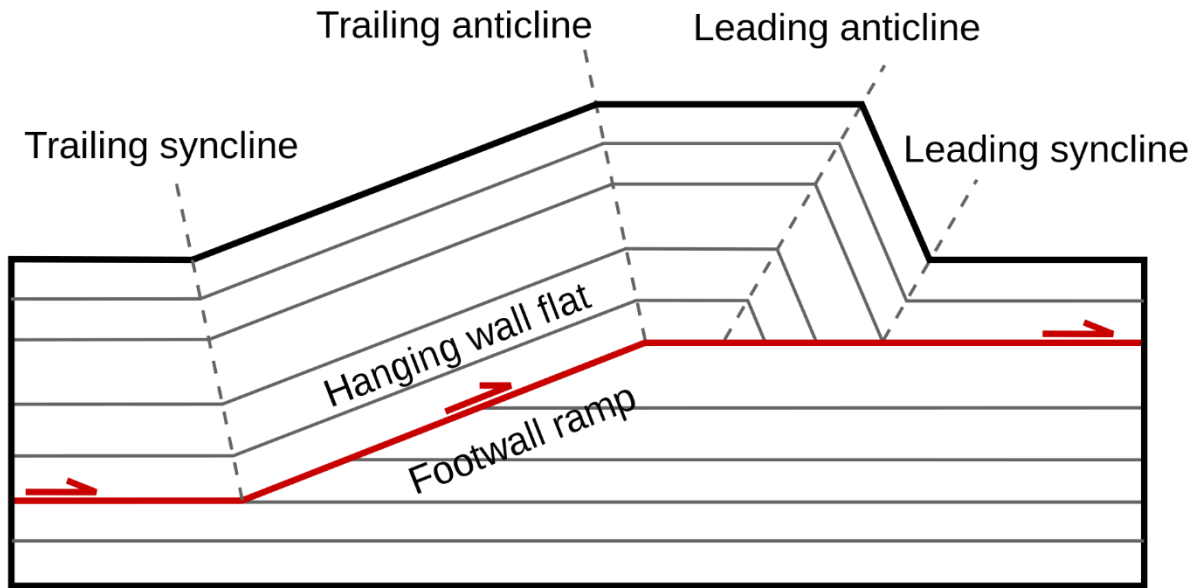
686 Fig. 2. Pink streaked with white Scaglia Rossa limestone is a pelagic sedimentary rock with forams and clay in a coccolith matrix dating
687 from the Late Cretaceous to middle Eocene. Mined from the Mt. Subasio quarry and used to construct the St. Francis basilica at
688 Assisi. Public domain Wiki Commons

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Fault-bend fold

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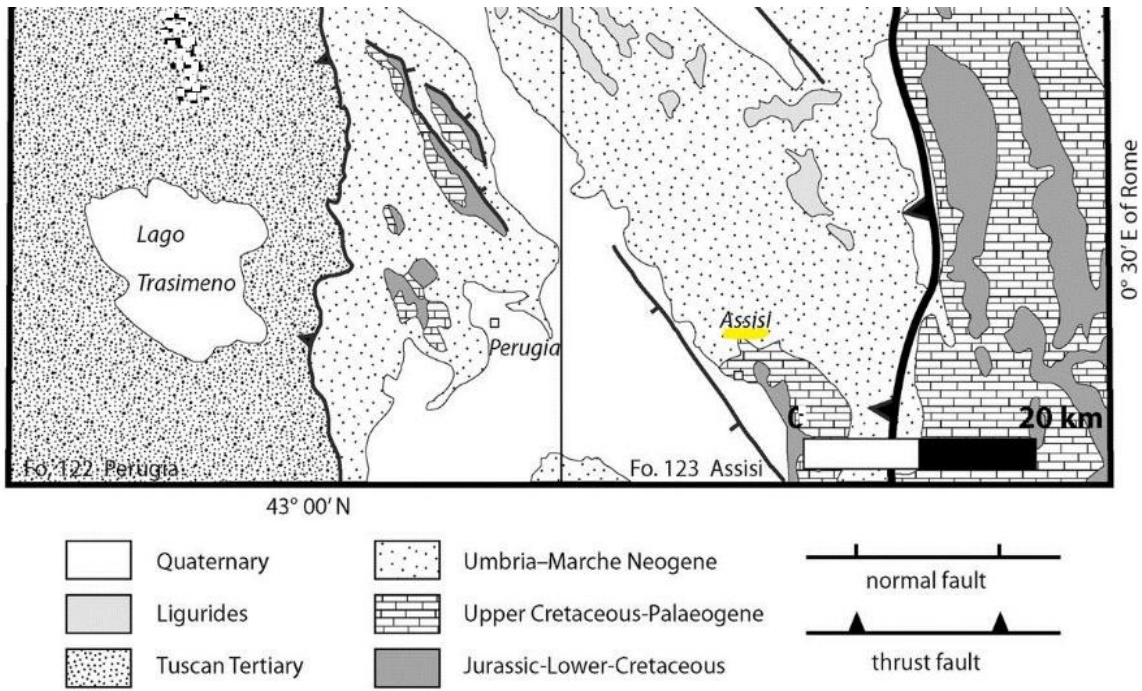
694 Fig. 3. Diagram of the anticlinal fold mountains formed by compression. Wiki Commons.

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700 Fig. 4. Geologic map of the area around Assisi. After G. Lena, et al. Geological Society, London 409,
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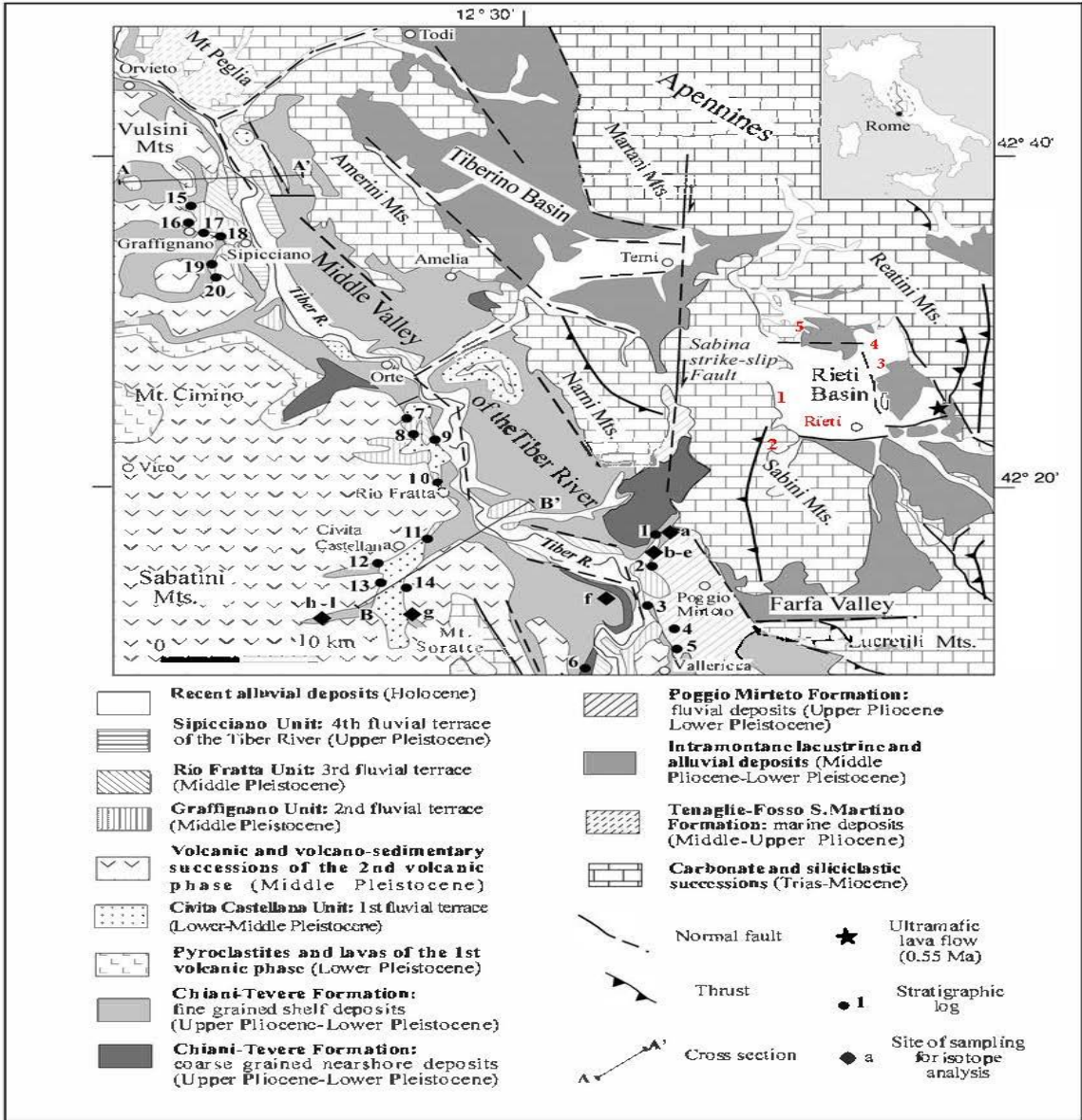
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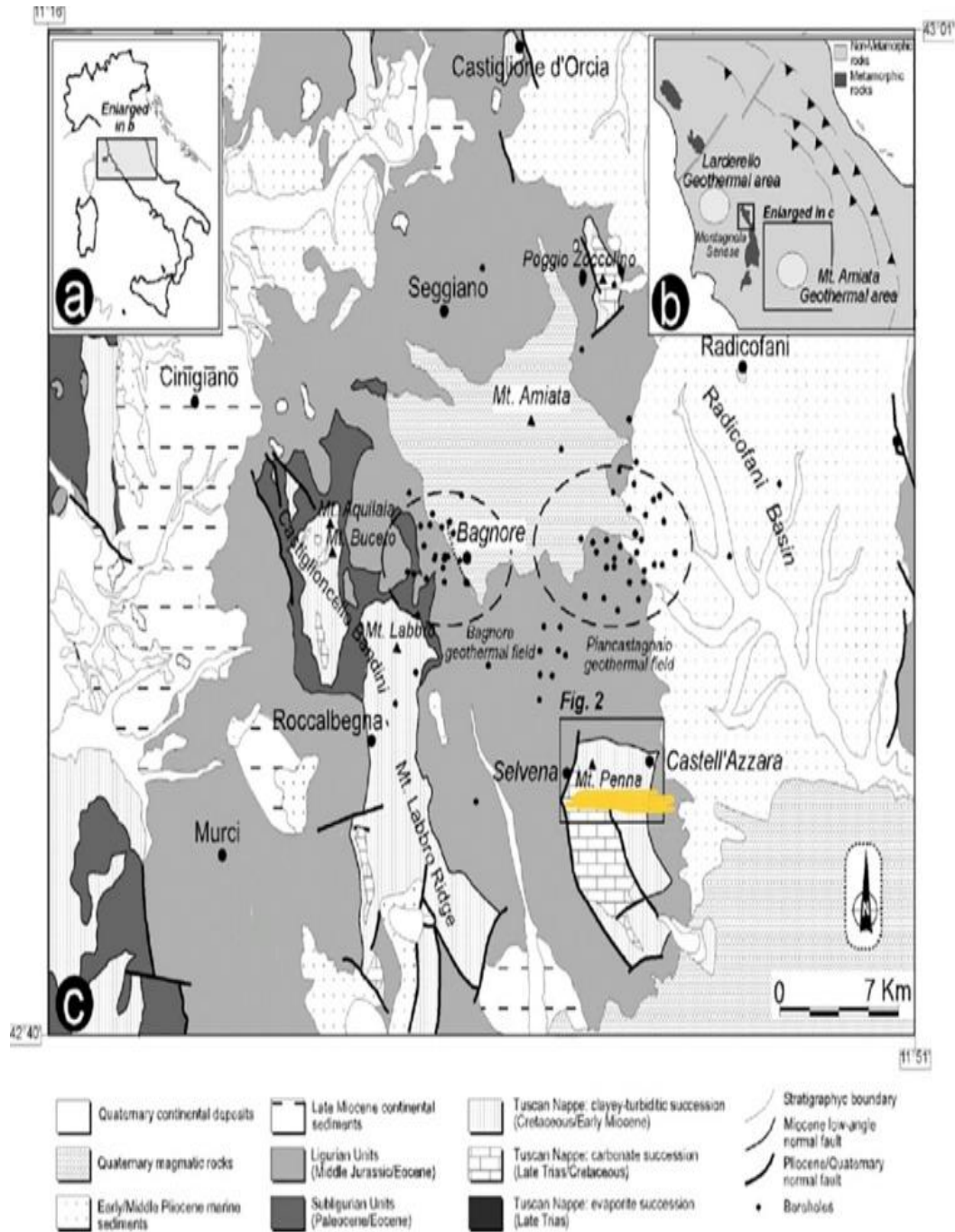
710 Fig. 5. Franciscan monasteries (in Red) 1) Greccio 2) Santuario di Fonte Colombo 3) Santuario della
 711 Foresta 4) Poggio Bustone 5) Labro. After Mancini, et. al. (2009).

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

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724

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

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

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

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741

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

745



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

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

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

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

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

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

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Fig. 17. The monastery at La Verna located on Mt. Penna composed of Miocene calcarenite. Public domain Wiki Commons



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Fig. 18. St. Francis Receiving the Stigmata. Giotto. 1318. Bardi Chapel, Santa Croce Basilica, Florence, Italy. Public domain Wiki Commons



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791 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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796 Fig. 20. The Legend of St. Francis: Miracle of the Spring 1297-1300 Upper Church, Assisi. Note the realistic depiction of the wave-
797 like marks of erosion along the bedding planes of the stratified limestone. Public domain Wiki Commons

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