Morphogenesis of karst poljes on Vis Island, Croatia

Morfogeneza krških polja na otoku Visu, Hrvatska

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Abstract

Karst poljes are the most characteristic feature of Dinaric karst area. The number of poljes identified on the island of Vis (Croatia) differs according to the various authors who have studied the island. Considering the various existing definitions of polje in previous studies, in this paper we propose a set of criteria for identifying poljes in karst terrain using Geographic Information System. This enabled the identification of six poljes on the Vis Island, whose formation is predetermined by tectonic structures. Moreover, processes are frequently inferred by neotectonic (both uplift and subsidence) according to the analysis of longitudinal and transverse profiles gradients affecting balance of these morphologies. Since they are not hydrologically active in present hydrological conditions, poljes on Vis Island can be considered to be paleo - overflow or structural poljes.

Keywords: karst polje, morphogenesis, Vis Island

Sažetak

Krška polja su najkarakterističnija značajka Dinarskog krškog područja. Broj definiranih polja na otoku Visu (Hrvatska) varira prema različitim istraživačima koji su proučavali otok. Uzimajući u obzir različite postojeće definicije polja korištene u prethodnim studijama, u ovom radu predlažemo kriterije za identifikaciju polja na krškim područjima koristeći Geografski Informacijski Sistem (GIS). Ovaj je pristup omogućio identifikaciju šest polja na otoku Visu, čija je formacija predisponirana tektonskim stukturama. Nadalje, analiza longitudinalnih i transverzalnih gradijenata profila polja pokazala je da su ovi procesi pod utjecajem neotektonskih pokreta (i izdizanja i tonjenja) što utječe na ravnotežu njihove morfogeneze. S obzirom da u današnjim hidrološkim uvjetima nisu hidrološki aktivna, polja na otoku Visu možemo smatrati paleo – preplavna ili strukturna polja.

Ključne riječi: krško polje, morfogeneza, otok Vis

Introduction

Although covering relatively small areas of the Dinaric karst (compared to the whole), karst poljes are the most characteristic feature of Dinaric karst area. In area with modest natural resources poljes were of essential value for population living here. Numerous scientists investigated karst poljes in Dinarides (e.g. Cvijić, 1895; Gams, 1973, 1978, 2005; Gavrilović, 1974; Roglić, 1974; Herak, 1972; Mijatović, 1984; Perica et al., 2002; Nicod, 2003; Bonacci, 2004; Ford and Williams, 2007), dealing with their morphology, hydrology, genesis and/or classification.

Thanks to favourable soil (Husnjak et al., 2008) and climate (Krklec et al., 2012a) characteristics Vis Island has rich agricultural tradition in karst poljes that goes back to ancient times (Zaninović, 1997). On the other hand, due to its remote position and relative isolation, only few studies focusing on karst poljes on Vis Island were done (Terzić, 2004; Husnjak et al., 2008).

In general, toponym “polje” (meaning field or arable land in Croatian) is widely used, but when referring to karst poljes can lead to confusion. For example in their study Husnjak et al. (2008) listed 17 karst poljes on Vis Island.

Among many definitions of karst poljes found in literature (e.g., Lehmann, 1960; Sweeting, 1972; Gams, 1973; Jennings, 1985; etc.) and taking into account hydrological situation on Vis island we decided to set criteria (following Ford and Williams, 2007; Mihevc, 2012; and Gams, 1978) that would help us to identify depressions on Vis Island that can be classified as poljes using Geographic Information System (GIS). Furthermore, an additional goal of this study was to try to reconstruct morphogenesis of karst poljes on Vis Island using GIS and available data.

Area of investigation

Vis Island belongs to the group of Central Dalmatian islands (Figure 1) and with total area of 89.7 km2 is the ninth largest among the Croatian islands (Duplančić Leder et al., 2004). The island of Vis is so-called “Hvar orientated” (W-E), which deviates from the “Dinaric direction” (NW-SE).

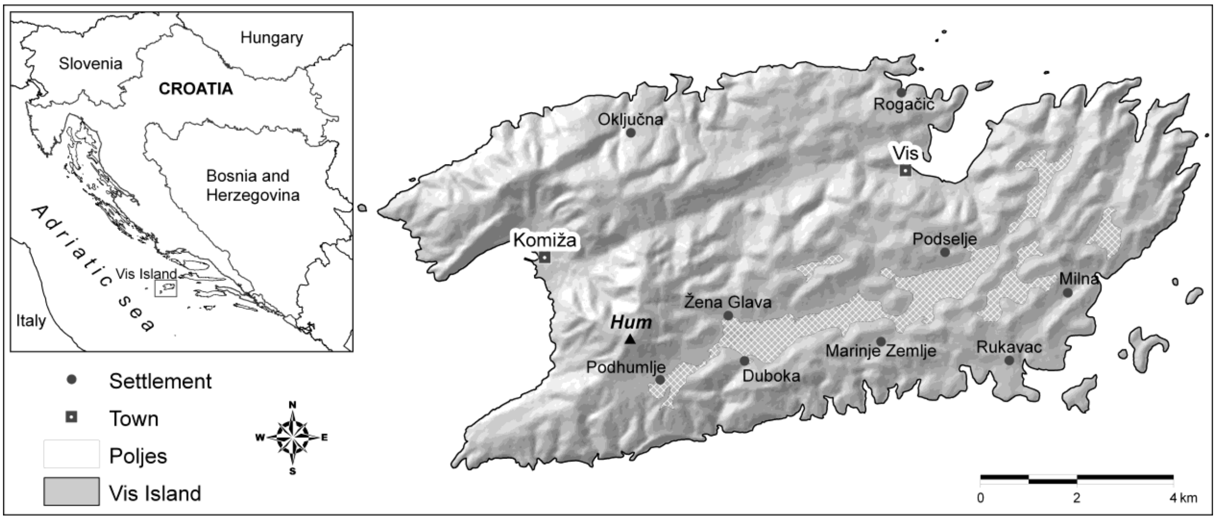

Figure 1. Position of Vis Island.

Morphologically, Vis Island is characterised by three ridges of ENE-WSW direction, formed of carbonates of Cretaceous age and separated by two valleys filled with impermeable deposits. Lithologically different area is Komiža bay, formed of impermeable volcanic and clastic rocks of Triassic age (Koch and Belak, 2003; Belak et al., 2005; Bukovac and Jamičić 2009), covered with breccias and conglomerates of Quaternary age (Palenik, 2005). These impermeable volcanic and clastic rocks had significant impact on morphology, especially on hydrology of the western part of Vis.

The elevation exceeds 500 meters on the western part of Vis Island, while on the eastern part does not exceed 300 m above sea level (Figure 4). Higher hills are formed in the limestones, while depressions (mostly in fault areas) are often located in dolomites. Ridge slopes (north and south) are dissected with gullies and dry valleys. Altitude increases from the coast to the interior, where the central ridge (extending from Komiža to Vis) divides the island to the northern and southern part.

Materials and Methods

This research has been conducted in three phases. The first phase consisted of field work on Vis island (including photo documentation and geomorphological mapping), while the second part was based on quantitative geomorphologic methods and analysis using Geographic Information System (GIS) (Burrough, 1986; Burrough and McDonell, 1998). After completing the second phase, the results were verified and confirmed by additional field investigation.

Geomorphologic methods and analysis (detailed geomorphological mapping, analysis of maps, photographs and orthophoto images) were related to the digital relief model (Kreveld, 1994; Ackermann, 1994; Šiljeg, 2010); made on the base of topographic map, scale 1:25000. By automatic overlay of primary (topographic map, scale 1:25000) and secondary data (geological map 1:100000 (Borović et al., 1975); hydrogeological map 1:100000 (Terzić, 2004)) and several thematic maps (hypsometric, inclination, tectonic, geomorphology) were made (Figure 2).

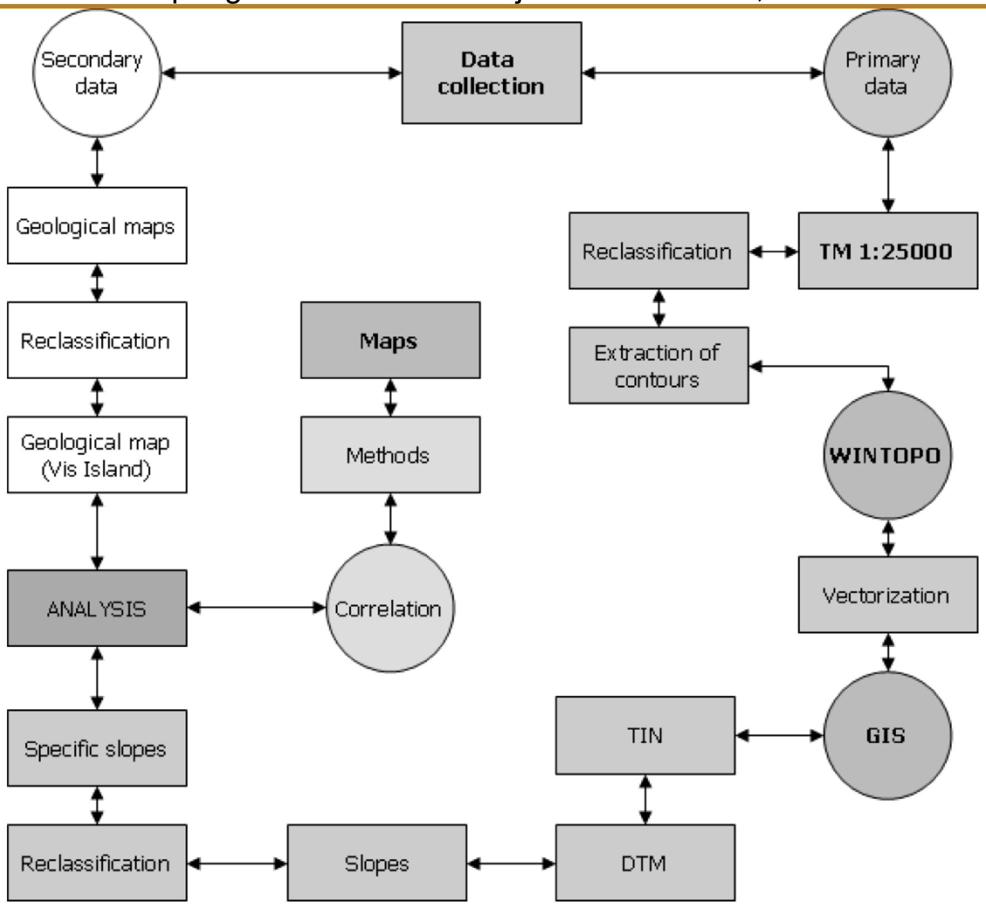

Figure 2. Methodology scheme developed and used in this research.

There are a number of algorithms for determining the slope inclination (Engelen and Huybrechts, 1981; Hickey et al., 1994) and in this paper we integrated algorithms in GIS programme. The principle of slope angle analysis is based on calculation of cells maximum change rate in relation to the surrounding neighbouring cells. In conceptual terms, inclination function fits the surface and z-values with 3x3 neighbouring cells (located around central cell) and inclination value is calculated using the average maximum technique (Burrough and Mcdonell, 1998). Network (composed of cells of equal size) is aligned with x (west-east) and y (north-south) geographic axis.

Rate of change in x direction for e.g. „h_e“ is calculated using algorithm:

$$h_x\ (dz/dx) = ((h_c + 2h_f + h_i) - (h_a + 2h_d + h_g)\ /\ (8 * d)$$

Rate of change in y direction for e.g. „h_e“ is calculated using algorithm:

$$h_y\ (dz/dy) = ((h_g + 2h_h + h_i) - (h_a + 2h_b + h_c)\ /\ (8 * d)$$

Using given results, inclination of cell „h_e“ is calculated using:

$$N = \sqrt{h_x^2 + h_y^2}$$

$$N(°) = ATAN\ (N)$$

Where d is horizontal / vertical dimension of cell and N is inclination of the cell.

Geology of study area

Lithology and hydrology

Clastic sediments with gypsum interbeds of upper Ladinian-upper Norian age (Koch and Belak, 2003) are the oldest deposits on Vis Island. They occur in Komiža bay in association with pyroclastics, spilites and diabases; and are in tectonic contact with Cretaceous carbonate rocks (Borović et al., 1977). Brown-grey limestones of Berriasian age are overlain by grey dolomites of the Valanginian-Hauterivian age. The upper stages of the Lower Cretaceous (Barremian, Aptian, and Albian) are represented with grey-brown limestones and overlain by the Upper Cretaceous (Cenomanian, Turonian) limestones and dolomites. Limestones of the Senonian age are the youngest Cretaceous deposits on Vis Island (Kapelj et al., 2002). Depressions and joint systems are partly (or completely) filled with Quaternary (Pleistocene) sediments (silty clays and talus breccias). Locally, bedded Quaternary sands are also found and are most likely, of eolian origin (Marković-Marjanović, 1978).

Sediment analysis (Miloš, 1986) shows that (depending on location) fine sand, silt and clay are dominant sediments in karst poljes of central part of Vis Island. Thickness of these sediments is up to 45 m (Crnolatac, 1954), according to data from drill hole in Veliko Zlo polje and is probably the consequence of tectonically formed gap burial. It is possible that, the average thickness of these deposits is just a few meters due to the tectonics (Palenik, 2005).

Talus breccias are widespread around poljes edges and are consisted of rock fragments (of local origin). Thickness of these deposits in some locations reaches 10 m (Palenik, 2005). It should be noted that talus breccias are often of tectonic origin and are important in poljes structure because they can be used to identify fault zones.

Marković-Marjanović (1978) identified Quaternary sedimentary phases on Vis Island. In the first phase (during Mindel-Riss interglacial period) silty clay derived from limestone surrounding area accumulated in poljes. Second phase, which occurred during Riss glacial period, was characterized by formation of scree cones (Podhumlje, Milna). In the third phase (Riss/Würm) fluvial conglomerates were deposited (in the area of Komiža bay), while the fourth phase (Würm I) was characterized by eolian sedimentation of quartz sands (found in Zlo polje, Borovo polje…) transported from NE direction. During the fifth phase brown paleosoils were formed (indicating more humid climate), while the sixth phase (Würm II) was characterised by poor eolian accumulation. The last phase which occurred after the end of Pleistocene (Boreal) was characterised by formation of brown soils.

Vis Island is a separate hydrogeological entirety with the water supply organized from its own aquifer. In Komiža bay several significant springs are located, but smaller appearances in Vis bay and along the east and west coast have been registered. Groundwater outflow was significantly slowed down by filling of caverns, cavities and discontinuities with fine grained material (silty-clayey and sandy material) (Kapelj et al., 2002).

According to their hydrogeological properties, following units can be distinguished on Vis Island (Figure 3, according to Terzić, 2004): Cretaceous water bearing calcareous carbonate (permeable); impermeable igneous, pyroclastic, and clastic rocks (function as the hydrogeological barrier); and dolomitic limestones in the base of sequence of poljes. The filling of caverns, cavities and discontinuities in the karstified carbonate rocks under the poljes is significantly increased, which leads to the decreased hydraulic conductivity of rock masses and today functions as a relative hydrogeological barrier (Terzić et al., 2002).

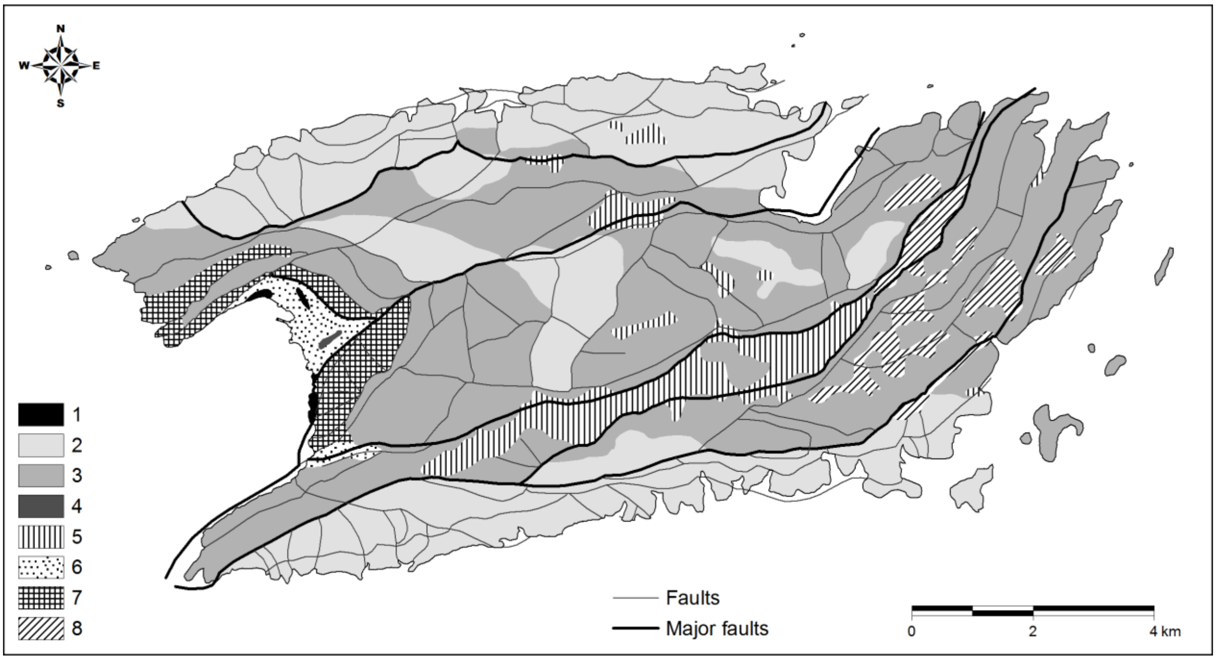

Figure 3. Hydrogeological map of Vis Island (according to Terzić 2004). 1 - Triassic clastic rocks; 2 - Upper Cretaceous limestones; 3 - Cretaceous calcitic dolomites; 4 – Triassic volcanic rocks; 5 – terra rossa with rock fragments; 6 – breccias and conglomerates; 7 – Neocomian dolomites; 8 – sands.

Tectonic evolution and structural features

Tectonically, Vis Island belongs to the unit called “Middle Dalmatian islands”, which is a part of the Adriatic–Dinaridic Carbonate Platform (Gušić and Jelaska, 1993; Pamić et al., 1998) or Adriatic Carbonate Platform (Vlahović et al., 2005). It represents a symmetric east-west oriented anticline whose axis subsides towards the east with average angle of 10 degrees (Palenik, 2005).

According to Marinčić (1997) who was dealing with neighbouring Hvar Island tectonics, this area underwent three tectonic phases: (1) Laramian tectonic phase at the end of the Upper Cretaceous, (2) Lutetian-Oligocene Pyrenean tangential phase and (3) Neogene-Quaternary Neotectonic tangential phase. These tectonic phases left distinguished landscape marks. Fault zones are formed during the Laramian tectonic phase at the end of the Upper Cretaceous. East-west fault zone in the southern part of the island was formed first, followed by NE-SW faults in the south-eastern part of the island. During Neogene-Quaternary Neotectonic tangential phase stress of N-S orientation additionally fragmented carbonate rocks (Palenik, 2005) (discussed in detail in section 8).

Geodetic measurements of recent stress using GPS-method in the period from 1994 to 1996 (Altiner et al., 1998; Prtoljan, 2003) showed that azimuth of recent stress is 349°, and that this area is tectonically very active (as indicated by the morphology of the marginal slopes of karst poljes, discussed in detail in section 6). Regional compression created tectonic framework for geomorphologic processes and development of karst forms (Šušnjar, 1967; Grandić et al., 1997a, 1997b, and Grandić et al., 2001).

Faults on Vis Island (often presented as fault zones few meters wide), are mainly subparallel to the longer axis of the island. Terzić (2004) outshines six major faults on Vis Island: Stupišće – Milna cove fault (F-1), Dračevo polje – Plisko polje – cape Stačine fault (F-2), Šćeđa – Žena Glava – Čumkovica – Dobra cove fault (F-3), Pizdica – Sv. Mihovil – Vis fault (F-4), cape Knez – Komiža – Sv. Mihovil fault (F-5) and V. Dragodir – Oključna – Sv. Juraj fault (F-6) (Figure 4).

These faults are of major importance for relief development. Carbonate rocks in fault zones are highly fragmented and due to weathering of those rocks, depressions along fault zones are formed. An example of the concurrence of fault zones with depressions is the zone of karst poljes between Dračevo polje – Plisko polje – cape Stačine fault (F-2) and Šćeđa – Žena Glava – Čumkovica – Dobra cove fault (F-3) (Figure 4). Faults (Figure 4) which stretch transversely to the direction of the major faults are of local importance.

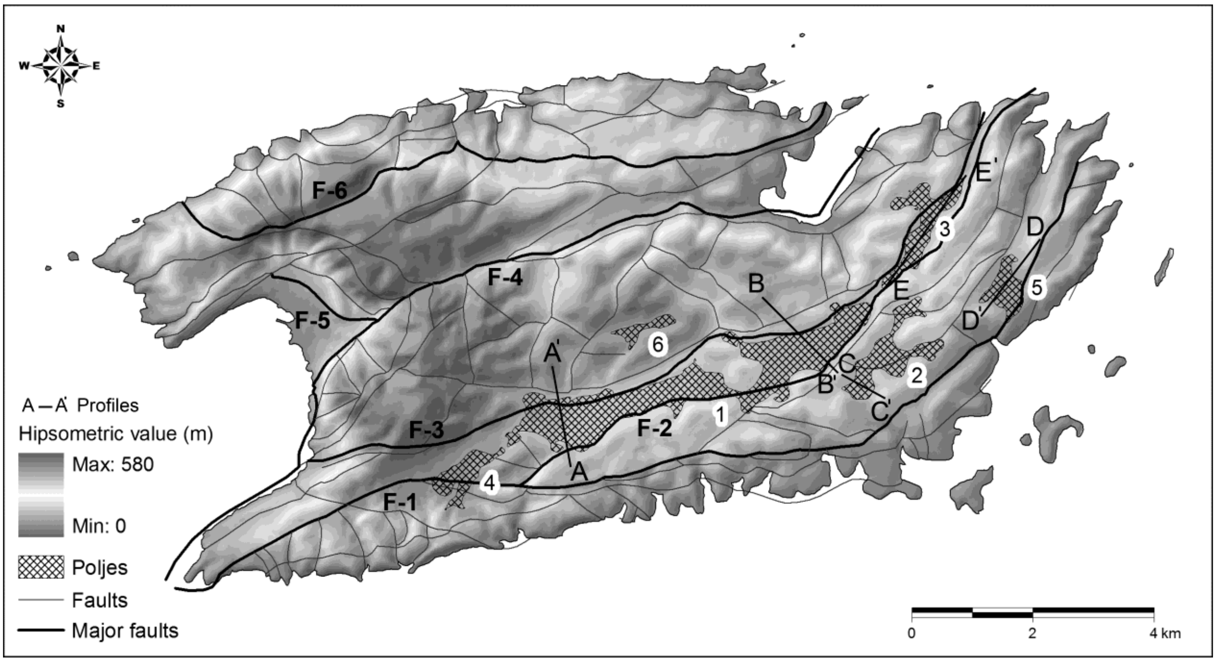

Figure 4. Hypsometry, faults (drawn according to Terzić 2004), karst poljes and profiles on Vis Island. 1 – Dračevo polje – Plisko polje; 2 - Mala Vošćica – Velika Vošćica – Malo Ljubišće – Veliko Ljubišće; 3 - Veliko Zlo polje – Malo Zlo polje; 4 – Podhumlje; 5 – Tihobraće polje; 6 – Čajno polje. Note that the names of some karst poljes here are the combination of two or more names used among residents of Vis Island.

Paleoclimate and present climate

In addition to lithology and tectonics important geomorphological factor that influenced the morphology of today's poljes are climate conditions in the past. For existence of surface water flow (especially in karst terrain) adequate rainfall and relatively high levels of groundwater are required (to prevent runoff of water to underground). Consequence of changes in amount of rainfall and temperature are global sea level variations (change of sea level changes erosion base).

During the last glacial maximum (about 30 ka to 19 ka BP) climate was cooler than the present. The average annual temperature in the northern mid-latitudes could have been lower than today by 5.6° K (Weaver et al., 1998), the global sea level was about -120 m relative to the present. Lower erosion base (result of lower global sea level) caused intensification of the karstic processes. In the Pleistocene cold phases, this part of the Adriatic basin was a steppe with grass and rare trees (Radić et al., 2007).

After this period climatic conditions had a tendency to warming (Bond et al., 1997). Melting of large ice masses caused increase in the global sea level. Two significant periods of the sea level rise (17.1 - 12.5 ka and about 9.5 ka BP) occurred (Fairbanks, 1989). In the period from 9 to 4.5 ka BP, climate in mid-latitudes was warmer and more humid. The average rainfall was increased by 50% than today at the same latitudes (Bond et al., 1997). Wetter early to mid-Holocene conditions have also been suggested (Bar-Matthews et al., 1997).

Warmest conditions have between estimated between 7 and 5 ka BP with summer temperatures being from 0.5-1.5°C (Davis et al., 2003; Renssen et al., 2009; Seppä et al., 2009) to 3.0°C higher than present (Burga, 1991, Renssen et al., 2012).

The present climate features of Vis Island are under significant Adriatic Sea influence. Vis Island is characterised by the Mediterranean climate type („Csa“) (Beck et al., 2006). Most of precipitation occurs during the cold period of the year, whereas during the summer time extreme drought is present. The average annual amount of precipitation in the period 1981 – 2009 was 711.4 mm (Krklec et al., 2012a).

Morphology of karst poljes on Vis Island

Karst poljes are large, flat-floored, enclosed depressions in karst terrains that are associated with the input and throughput of water and in many aspects can be considered inliers of a normal fluvial landscape (Ford and Williams, 2007). “They differ from other closed depressions in size and their large flat bottoms which formed as baselevel corrosion plains. Typical forms have a sinking river, steep slopes and a sharp transition between the polje floors and slopes. The bottom of the polje may be covered by sediments“ (Mihevc, 2010).

Considering their hydrological and morphological characteristics, Gams identifies five types of poljes (Gams, 1973; Gams, 1978; Gams, 1994). These are: border polje, piedmont polje, peripheral polje, overflow polje and baselevel polje. Ford and Williams (2007) reduced them to three basic types: border poljes, structural poljes and baselevel poljes. As before mentioned due to toponym confusion it was essential to review all poljes on Vis Island. In order to do so, it is important to point out present hydrological situation on Vis Island. Nowadays there are no surface water flows. There are two ponors (in Velo polje and in Milna) and one puddle called Lokva located in the middle of Dračevo polje. Due to lithology (weathering of dolomites into sand sized particles), change of climate conditions and long-term agricultural activity on this area, we presume that other ponors could have existed in the past when poljes were more hydrologically active, but nowadays are filled with sediments.

Having this in mind we decided to set criteria (following Ford and Williams, 2007; Mihevc, 2010; Gams, 1978) that would help us to identify depressions on Vis Island that can be classified as poljes using GIS. Those criteria were: (1) flat floor in rock or in unconsolidated sediments; (2) closed basin with steeply rising marginal slope at least on one side; (3) flat floor should be at least 400 m wide. According to those criteria and field investigation, six karst poljes on Vis Island were determined. Polje No. 6 does not match the last criterion, but we decided to include it due to morphology of depression.

Poljes on Vis Island appear in a form of enclosed morphological depressions, and have been developed along tectonic lines (Krklec et al., 2012b). The dry valleys are oriented toward the poljes, in the E(SE)-W(NW) and W(NW)-E(SE) direction. Slope inclination in poljes is generally <5° (0-2° in the central parts of poljes and 2-5° on the edges) (Figure 5).

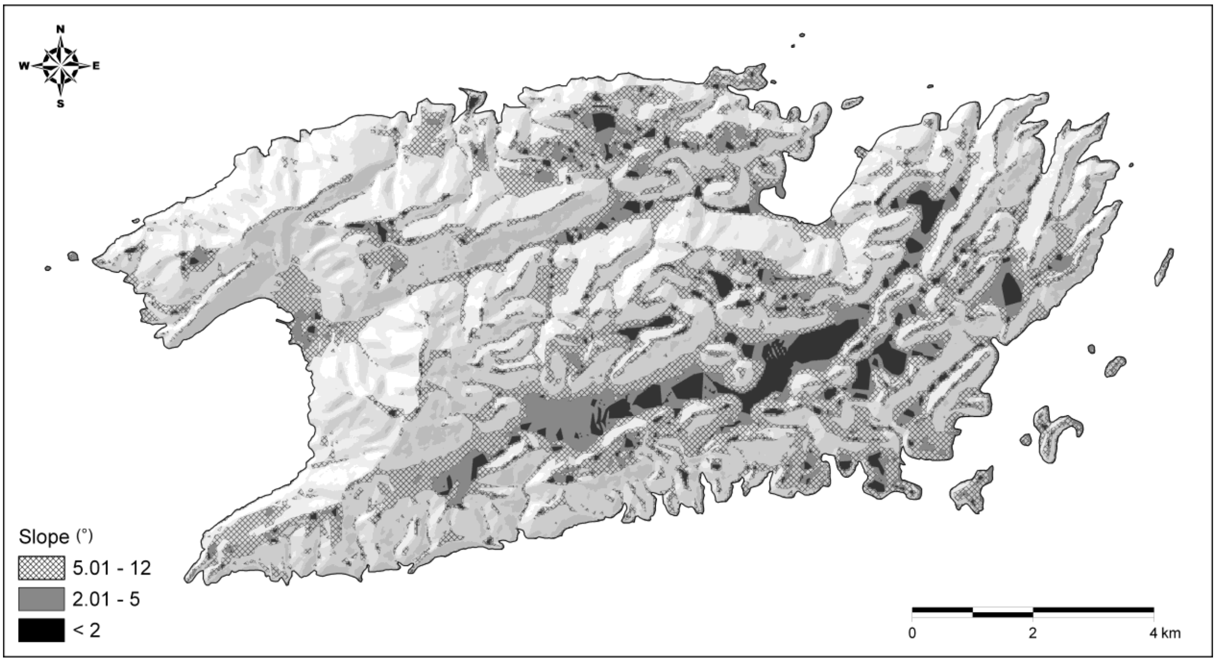

Figure 5. Slope inclination map (<12°).

Table 1. Total surface and elevation of karst poljes on Vis Island.

Polje	Surface (km^2)	Elevation (m)	
		min	max
Dračevo polje - Plisko polje (1)	3.56	110	227.14
Mala Vošćica – Velika Vošćica – Malo Ljubišće – Veliko Ljubišće (2)	0.78	105	141
Veliko Zlo polje – Malo Zlo polje (3)	0.66	100	130
Podhumlje (4)	0.43	218	267.08
Tihobraće polje (5)	0.38	60.6	90
Čajno polje (6)	0.17	240	250

Poljes on Vis Island are: Dračevo polje - Plisko polje (1); Mala Vošćica – Velika Vošćica – Malo Ljubišće – Veliko Ljubišće (2); Veliko Zlo polje – Malo Zlo polje (3); Podhumlje (4), Tihobraće polje (5) and Čajno polje (6); and are located on the south and east of the island (Figure 4). The largest is Dračevo polje - Plisko polje system, which covers the area of 3.56 km2, and the smallest is Čajno polje with area of about 0.17 km2. The total area of poljes on Vis Island is 5.97 km2 (Table 1).

In order to get more detailed insight into poljes morphogenesis, profiles of poljes and surrounding slopes were determined (some of the examples are shown in Figure 6). The analysis was based on the digital elevation model (Figure 4, 6). Parsons (1988) recognized that slope profiles may be planar, concave, or convex in plan. Convex slopes indicate younger uplifts and are dominated by destructive processes, while concave slopes are genetically older and are dominated by accumulation processes (Pahernik, 2007). In this area younger uplifts occurred in the Neogene-Quaternary Neotectonic tangential phase characterised by stress of N-S direction (Aljinović et al., 1981). This new stress regime leads to the landscape transformation, refolding of the existing structures and the formation of the new ones (Palenik, 2005) as it can be seen on profiles A-A', B-B', C-C', D-D' and especially on cascade longitudinal profile E-E' (Figure 4, 6). Reactivation of the existing discontinuity during neotectonic activity is a consequence of the fact that each new tectonic cycle, with the new regime of the main stress direction, uses existing discontinuities (that take a part of directed pressure).

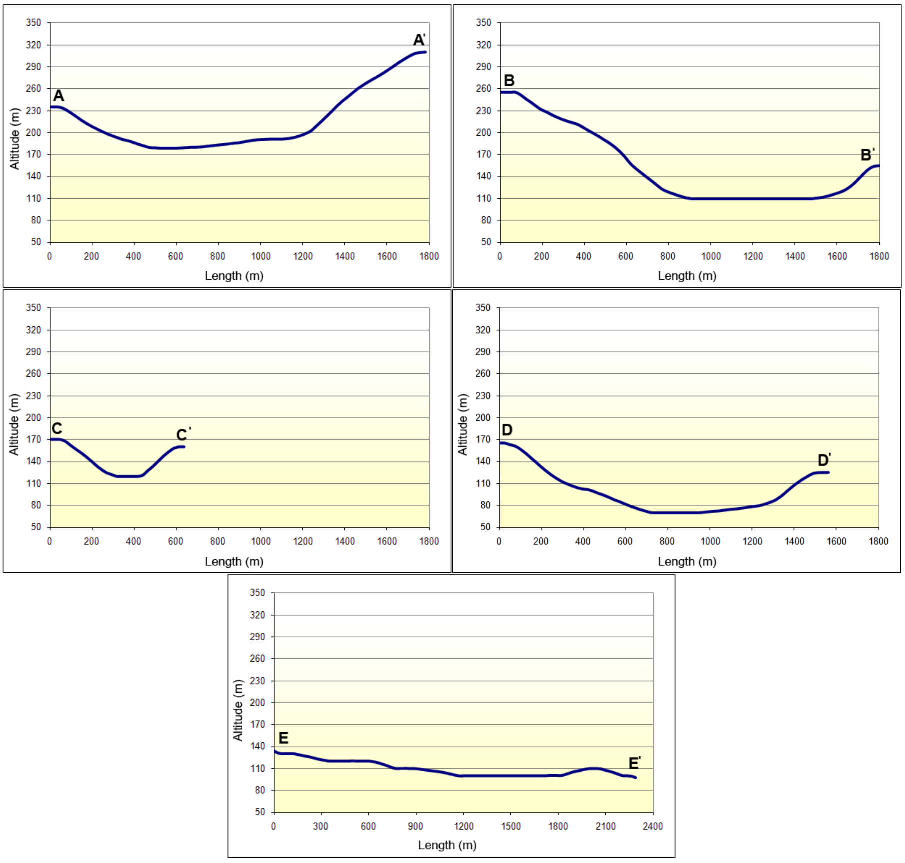

Figure 6. Representative profiles of poljes and corresponding slopes.

When comparing the longitudinal and transverse poljes profiles and tectonics (Figure 4, 6), it can be seen that the existing faults and fracture systems are in almost "ideal position" for the reactivation in neotectonic cycle.

GIS analysis and field study showed that the convex sections along the slope are in the poljes No.1 and 2 (dominated by uplifting). On the slopes of poljes No.1, 2, 3, 5 and 6 concave profiles appear (dominated by lowering), while planar profiles (processes of uplifting and lowering are in balance) were determined on the slopes of poljes No.1, 2, 3, 4 and 6. Combinations of convex and concave profiles (segments of a slope) can be found on the slopes of poljes No.1, 3, 4 and 5. The situation is more complex here, because at the same time on different slope parts, different processes are active.

Anthropogenic impact

Since ancient times, due to its mild climate, poljes of Vis Island were suitable for agricultural production. Through the ages and even today, viticulture was the most important economic sector on Vis Island (Novak, 1961). Karst poljes represent the morphological type that has the largest share of cultivated area (while the degraded areas on closer or more distant high ground generally have the function of pastures).

Although when speaking about morphogenesis of karst poljes human impact is trivial and has nothing to do with karst polje formation and development, human activity can be important for the origin of sediments. Anthropogenic impact in poljes on Vis Island is most visible on surrounding slopes. Construction of terraces and dry stone walls prevented surface runoff, erosion and consequently sediment input in karst poljes. Cultivation of poljes bottoms could have erased traces of bottom morphology. In addition, it is possible that people filled ponors with sediments (or garbage, or other objects that would block it) in order to prevent fertile soil runoff or to prevent animals to fall into. This was common practice in the past in the Dinaric karst area (e.g. in Popovo polje, Bosnia and Herzegovina (Lučić, 2007)).

Nowadays due to abandonment of agriculture reforestation is present on the surrounding slopes. This additionally prevents sediment input to poljes.

Morphological evolution of poljes on Vis Island

Faults that dissected entire island predisposed formation of poljes. Poljes on Vis Island are developed in the area of wide fault zones (Figure 4) where during lower sea level in the past water was able to circulate and karstify carbonate rocks. Later on when climate conditions changed and climate become more humid (see section 5 for details) caverns, cavities and discontinuities in the karstified carbonate rocks were filled with fine grained material (silty-clayey and sandy material) (Kapelj et al., 2002). This material decreased circulation of water and made surface of poljes impermeable (functions as a relative hydrogeological barrier, Terzić et al., 2002).

By considering the tectonic development of the area (Marinčić, 1997) and Vis Island (Palenik, 2005), and correlating the available maps (geological maps (Borović et al., 1975; Palenik, 2005), tectonic structure map (Palenik, 2005) and hydro-geological map (Terzić, 2004)), it is possible to reconstruct the development of poljes on the island.

It can be assumed that the oldest poljes (or parts of poljes) are formed in the east-west fault zone in the southern part of the island (Figure 7a), which was formed during the Laramian tectonic phase at the end of the Upper Cretaceous. These poljes (or part of poljes) are: Podhumlje, Dračevo polje and Čajno polje, and are younger than Laramian tectonic phase. Podhumlje and Dračevo polje are larger than Čajno polje, because they are formed closer to the central fault zone part (since rocks are strongly fractured, surface of the rock exposed to weathering is increased (in faze of karstification) which leads to further fragmentation of rocks. Those particles often block cavities, preventing water drainage and forcing formation of surface water flow, which results in flattening the floor and forming a polje.

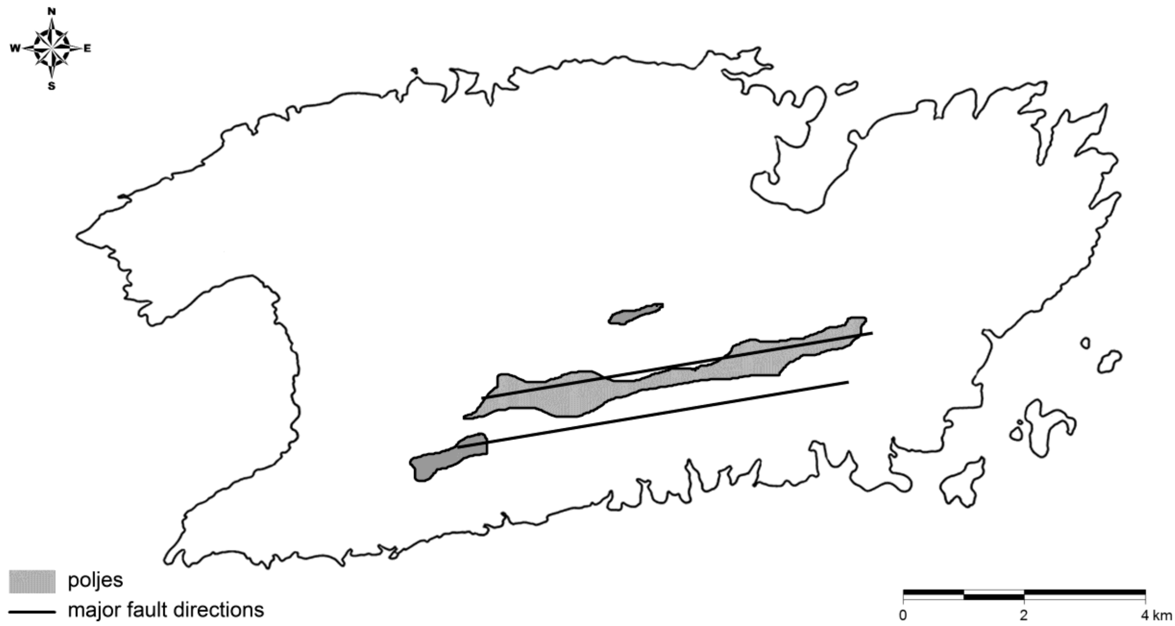

Figure 7a. First phase of poljes formation after Laramian tectonic phase.

Figure 7b. Second phase of poljes formation.

During the same tectonic phase (but later) NE-SW faults on the south-eastern part of the island were formed. Poljes (or part of poljes) formed in this zone include: Plisko polje, Mala Vošćica – Velika Vošćica – Malo Ljubišće – Veliko Ljubišće, Tihobraće polje and Veliko Zlo polje – Malo Zlo polje (Figure 7b).

Depressions on the northern part of the island are probably formed after Pyrenean phase when that part of the island was faulted. During Neogene-Quaternary orogenetic phase characterised by pressures of north-south direction depressions on Vis Island get their final appearance.

Conclusions

Formation of poljes on Vis Island was predisposed by tectonic movements which created tectonic framework for geomorphologic processes and development of karst forms. Regardless of the particularities of each karst polje separately, all poljes are developed close to the local water table. Today, Vis Island is characterized by the lack of permanent surface water flow and poljes are not hydrologically active in present hydrological conditions. Therefore, the formation of poljes occurred during a more humid period in the geologic past, or in conditions when the rainfall was greater than the potential evapotranspiration (Šegota, 1963; Gams, 2004).

Above described poljes on Vis Island have their bottoms filled with fine grained material (silty-clayey and sandy material) which acted as a barrier and forced groundwater to flow on the surface and sink on the other side of the poljes. Therefore poljes on Vis Island can be considered to be overflow poljes (according to Gams, classification (Gams, 1973; Gams, 1978; Gams, 1994)) or structural poljes (according to Ford and Williams's classification (2007)).

Analysis of selected poljes slope profiles showed that there is no dominance of a single morphological type of slopes present within poljes and that the combination of convex, concave and planar types is usually present. This method is maybe not applicable on poljes on Vis Island, but clearly shows that the poljes formation was complex.

Acknowledges

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