Geomorphological map and land units at 1:200,000 scale of the Siena province (Southern Tuscany, Italy)

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Geomorphological map and land units at 1:200,000 scale of the Siena Province (Southern Tuscany, Italy)

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Abstract

Small scale geomorphological maps and land unit classification of large areas are not common due to the high degree of generalisation required to represent landforms originally mapped at larger scale (i.e. 1:10,000). Here we present a 1:200,000 scale geomorphological map of the Siena Province (Tuscany, Italy) where the landforms related to different processes have been synthesised into a map representing the main landscape units. The process of generalisation follows the overlapping of the main processes and landforms grouped in 6 main categories: geology, land use, slope, structural/selective erosion, gravity and running water. The final map indicates the presence of seven main homogeneous landscapes characterised by typical associations of landforms and processes. The reference scale allows the analysis of the entire Siena Province and may be used for landscape evaluation, including natural hazards and related susceptibility.

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1. Introduction

In the last few decades many geomorphological mapping projects have been performed in different regions of Italy. However, few small scale geomorphological maps have been realized because of the complexity of the Italian geomorphological setting and the difficulties in synthesizing a large amount of information. We present a 1:20,000 scale geomorphological map of the Siena Province where seven main landscape units are mapped and described analysing the distribution and frequency of the landforms and their relations with the factors responsible for landscape modelling. We also present 1:500,000 scale maps of the same area reporting the major landforms (gravitational, running water and selective erosion) as well as geology, land use and slope gradient. The data provide a tool for the evaluation of landscape evolution and dynamics and can be used as a base for geomorphic susceptibility analysis and other purposes of landscape evaluation and valorisation.

2. Geological and geomorphological setting

The Siena Province extends for 3821 km^2 in the southern part of the Tuscany Region (Northern Apennine) (Figure 1). The province has about 250,000 inhabitants with a density of 66 persons/km^2; about 1/5 of the population lives in the town of Siena located in the northern part of the province (Figure 1). Minor towns and villages are scattered in the hilly areas of the Province. The climate is strongly influenced by the orography, being mainly sub-humid with minor per-humid areas close to the main ridges. The precipitation ranges between 700 mm/y and 1300 mm/y in the Mt. Amiata (Figure 1). The mean temperature is about $14°C$ with lowest values in January and highest in July, whereas in the Mt. Amiata the mean temperature is $9°C$. Snow cover affects the upper part of the Mt. Amiata during winter for over two months a year while is sporadic in the rest of the area (Figure 2).

For generalization, due to the scale of the map we subdivided the bedrock into major lithostructural units (Figure 3) according to their different response to geomorphic processes:

- *Metamorphic rocks* (green schist facies, Paleozoic-Mesozoic, MR): schists, metarenites, metaconglomerates, metadolomites and marbles belonging to Paleozoic Basement (PB) and Mesozoic Metamorphic Tuscan Units (MTU);

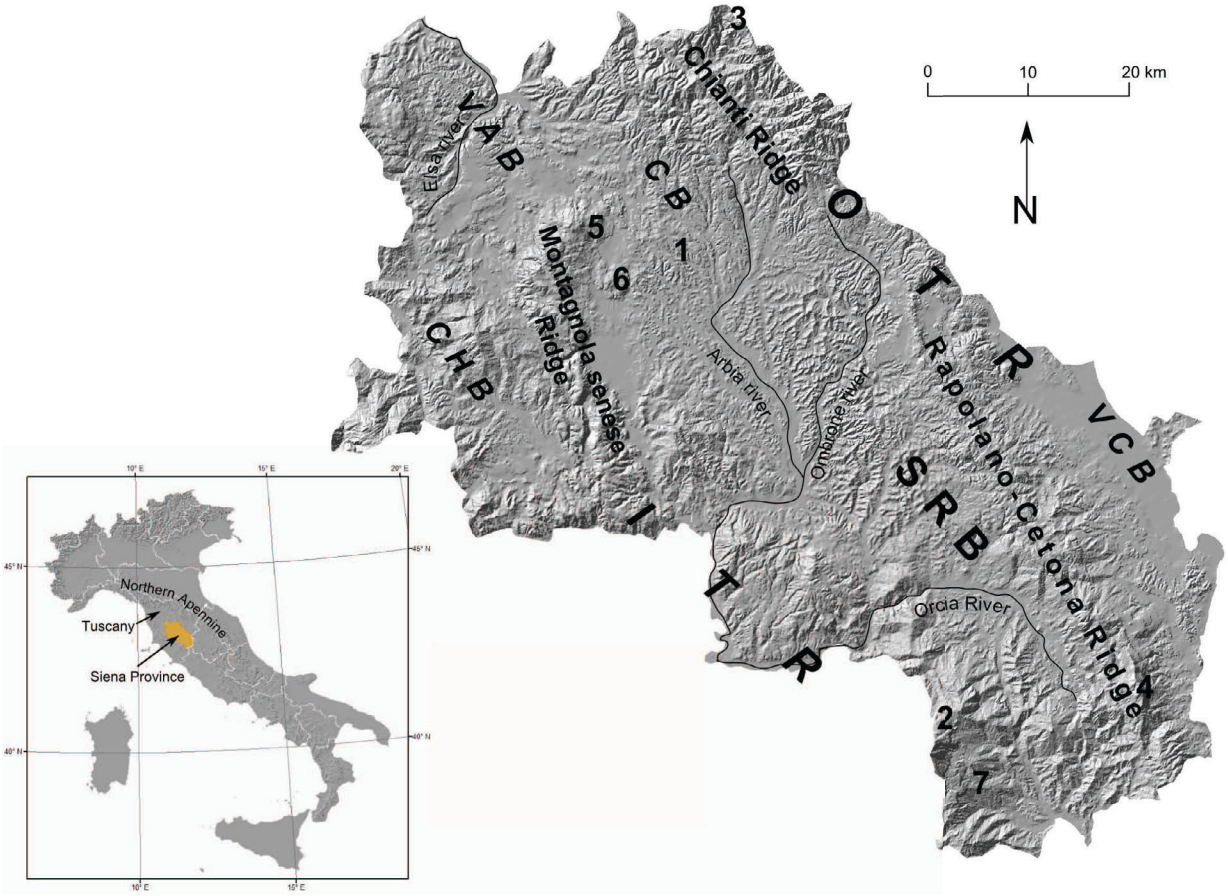

Figure 1. The main physiographic elements of the Province of Siena. Acronyms: OTR - Outer Tuscan Ridge; ITR - Inner Tuscan Ridge; SRB - Siena-Radicofani Basin; VCB - Valdichiana Basin; CHB - Chiusdino Basin; CB - Casino Basin; VAB - Valdelsa basin. Numbers: 1 - Siena; 2 - Mt. Amiata; 3 - Montegrossi; 4 - Mt. Cetona; 5 - Montemaggio; 6 - Grotti; 7 - Piancastagnaio.

- *Marine limestones, marly limestones, cherty limestones* (Non Metamorphic Tuscan Units, Mesozoic, LNMTU): massive and stratified micritic and cherty limestones overthrusted on the MR;
- *Marine arenaceous rocks* (Non Metamorphic Tuscan Units, Oligocene to Miocene ANMTU): thick layers of siliciclastic sandstones with local marly and pelitic alternances, gradual transition to LNMTU;
- *Marine Ligurian and Subligurian allochtonous complex* (Cretaceous-Eocene, LSAC): clays, marls, limestones, sandstones locally including basalts and ophiolites frequently arranged in chaotic complexes. The lower boundary are low angle normal faults and/or overthrusts;
- *Coastal and continental deposits* (Miocene, MCC): calcareous breccias, conglomerates, sands and clays unconformably overlying the older rocks within synform basins;

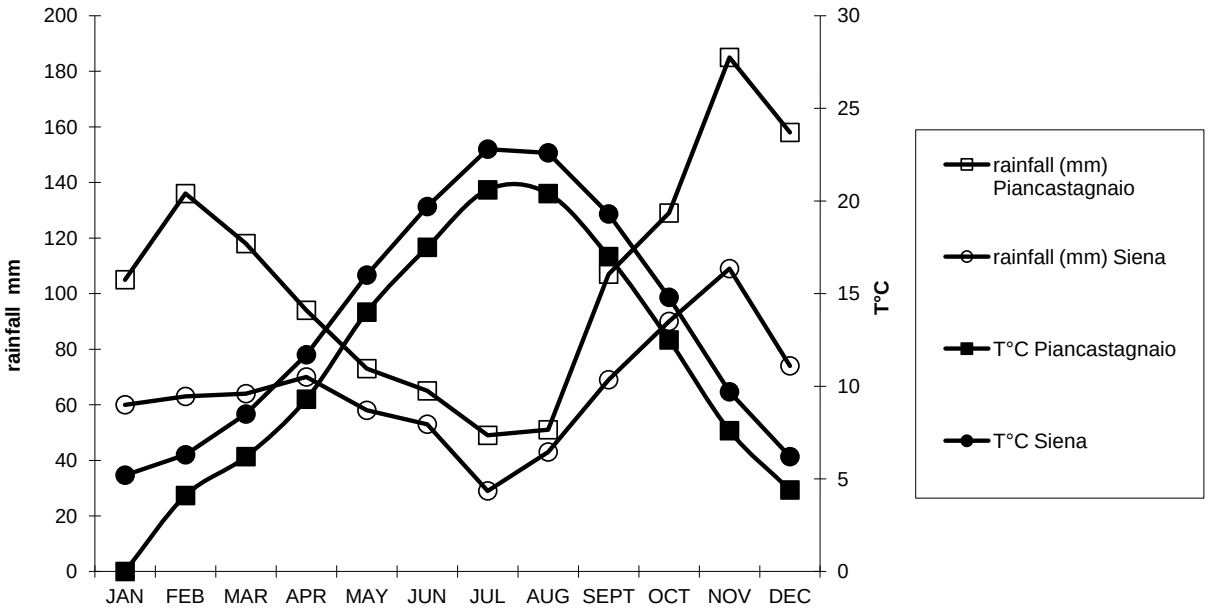

Figure 2. Mean monthly rainfall and temperature for Siena and Piancastagnaio (see Figure 1).

- *Marine clays* (Early-Middle Pliocene, CCC) unconformably overlying the older rocks;
- *Coastal sands and conglomerates* (Early-Middle Pliocene, PCC) unconformably overlying the older rocks;
- *Volcanics* (300-180 ka (Ferrari et al., 1996, VU) dacitic and riodacitic lava flows of the Mt. Amiata volcano;
- *Travertines and calcareous tufa* (Middle-Late Pleistocene, TCT): phytostromales, phytohermales, phytoclastic and lacustrine calcareous tufa, microcrystalline travertines.

The landscape is characterised by two NNW-SSE trending ridges (Figure 1) corresponding to the most resistant lithologies: the 'Outer Tuscany Ridge' (OTR) to the east and the 'Inner Tuscany Ridge' (ITR) to the west. The OTR is subdivided into the Chianti Ridge to the north (Montegrossi, 823 m.a.s.l., Figure 1) mostly made of ANMTU and LNMTU and the Rapolano-Cetona Ridge (Mt. Cetona, 1148 m.a.s.l. Figure 1) to the south, made of LSAC and LNMTU. The ITR in the central-southern part is mostly made of LSAC and by MR in the north-western sector (Montagnola Senese Ridge, Montemaggio 671 m.a.s.l, Figure 1). On top of both ridges remnants of marine PCC are preserved up to ca. 700 m.a.s.l. (Passerini, 1964; Liotta and Salvatorini, 1994; Boscato et al., 2008) indicating the maximum amount of vertical uplift since the Middle Pliocene. The ridges separate three major basins with low relief energy (Figure 1). The Siena-Radicofani basin (SRB), in the central part, is separated by a minor saddle carved in MCC in the Casino Basin

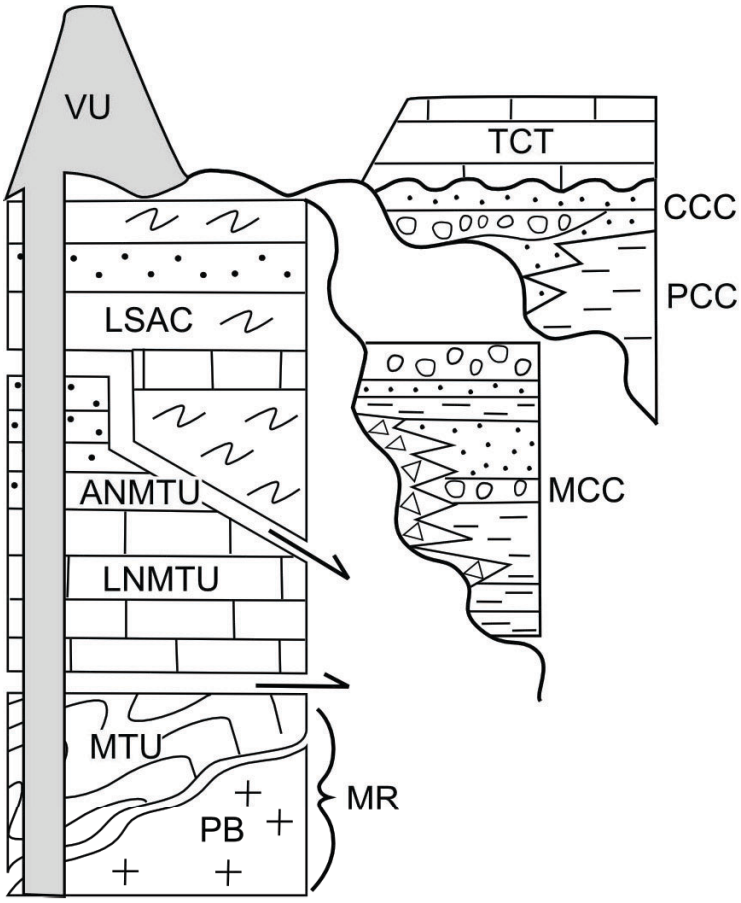

Figure 3. - Litho-structural scheme of the bedrock of the Siena Province. MR - Metamorphic rocks; PB - Paleozoic Basement; MTU - Metamorphic Tuscan Units; LNMTU - Calcareous Non Metamorphic Tuscan Units; ANMTU - Arenaceous Non Metamorphic Tuscan Units; LSAC - Marine Ligurian and Subligurian allochtonous complex; MCC - Coastal and continental deposits; CCC - Marine clays; PCC - Coastal sands and conglomerates; VU - Volcanics; TCT - Travertines and calcareous tufa.

(Bossio et al., 2002, ; CB, Figure 1) from the Valdelsa Basin (VAB) to the north. The SRB has an hilly landscape modelled on CCC clays to the south and on PCC sands and conglomerates to the north and south east. The latter sediments also crop out in the VAB. To the east of the OTR there is part of the larger Valdichiana basin (VCB) while to the west of the OTR there is the Chiusdino Basin (Bossio et al., 1992; Riforgiato et al., 2005, ; CHB, Figure 1) mostly filled with CCC and to a minor extent by PCC. The highest elevation is reached in the isolated volcanic relief of Mt. Amiata (1780 m.a.s.l.) located in the south-western border of the Province. As regards the Plio-Quaternary evolution of the area, syn-sedimentary tectonic movements were responsible for the creation of synform basins in the Early Pliocene (Coltorti and Pieruccini, 1997; Coltorti et al., 2007; Brogi, 2011) locally associated with normal faults such as the one bounding the Mt. Cetona to the west (Liotta and Salvatorini, 1994). Planation processes of both basin and ridges are recorded at least during Middle Pliocene (Coltorti and Pieruccini, 1997; Coltorti et al., 2007). Most of the tectonics during the Quaternary are characterised by vertical uplift

and related deepening of the drainage network (Coltorti and Pieruccini, 2002). Erosion mostly affected softer terrains of the Mio-Pliocene basins. No evidence for Quaternary fault activity has been observed throughout the area but lineaments and morphotectonic features suggest the re-exhumation of older structures. Hot spring travertine and calcareous tufa deposition is mostly related to thermalism along old structures and their interaction with Quaternary climatic oscillations (Goudie et al., 1993; Cilla et al., 1996). The flat areas, mostly on alluvial deposits and alluvial terraces, are limited to the main valley floors and to the karstic depressions.

At a smaller scale the drainage network is almost parallel to the main ridges and is structurally controlled; dendritic patterns characterize the clayey dominated basins while linear and angular patterns dominate across the ridges. The Mt. Amiata volcanic relief has a radial pattern.

The main river in the southwestern part is the Ombrone, draining westward with the main tributaries Arbia and Orcia Rivers; the Elsa River in the northernmost sector and in the easternmost part of the Province (Valdichiana basin) the network of artificial channels tributaries of the Chiana river (mostly out of the Province) are tributaries of the Arno basin.

3. Methods

The geomorphological map results from 1:25,000 scale field mapping and aerophoto survey. The legend of the 1:25,000 maps follow the guidelines of the Italian National Geological Survey for the 1:50,000 scale geomorphological maps of Italy (Geological Survey of Italy, 1994), although in the 1:500,000 scale maps some of the colours and symbols have been changed due to problems of representation. Punctual, linear, polygonal landforms and related deposits are classified according to the prevalent geomorphic process (in this case selective erosion, volcanic, superficial running water, gravity, karst, anthropic, polygenic). The field maps have been digitalized in ESRI ArcGIS coupled with a database structured following the legend. The generalisation of the 1:200,000 scale map has been processed primarily using an expert based process. The dimensions of the Province and its complexity and variability in terms of geology, relief, drainage, surface processes and land use make it difficult to obtain an automatic landscape system and related geomorphic assessment (Mackaness et al., 2007; Smirnoff et al., 2008). The digitalized 1:25,000 scale geomorphological map underwent statistical analysis regarding the relationships between landforms, geomorphic processes, bedrock and land use. However, in order for the map to be readable, the process for the simplification of polygons, elimination of microfeatures and aggregation of groups required a high de-

gree of subjective selection and, during every step, a number of parameters entered by the user.

Three synthetic maps of the main geomorphic processes at 1:500,000 scale are included in the geomorphological map: 1) Landslide inventory map subdivided into flows, slides/glides and Deep Seated Gravitational Movements (DSGM) following their activity status; 2) Running water erosional processes, such as gullies, badlands and biancane (small dome shaped denudational features; Vittorini, 1977; Guasparri, 1978) following their activity status; 3) Selective erosion features, such as escarpments and structural surfaces including volcanic landforms (lava flows surfaces) and main morphotectonic lineaments. Other 1:500,000 scale maps attached include: geological map obtained from the 1:10,000 scale Geological Map of Tuscany Region (Regione Toscana Web Site, 2011), slope classification from a 20 m DTM derived from the 1:10,000 scale topo maps of the Tuscany Region and CORINE land cover (European Commission, 1994).

4. Geomorphology and landscape classification

Seven main landscape systems have been recognised, some of them are subdivided into minor landscape units.

1. **Landscapes of the Mountain Ridges (MOR)** - Mainly steep and forested slopes, locally affected by landslides including Deep Seated Gravitational Movements (DSGM). They are further subdivided into:

   (a) *Chianti Ridge* (MORch) type area, mostly on sandstones and marly limestones with local stepped slopes due to selective erosion and remnants of summit planation surfaces (Figure 4). The drainage network is relatively dense, linear to dendritic, with deep valleys and gorges;

   (b) *Rapolano-Cetona Ridge* (MORcr) type area, mostly on limestones and marly limestones; slopes are steep and short while the summits are commonly planated; only the Cetona Mountain rises from the planation surface (Figure 5). Catchments are small and the low density drainage network has a mainly linear pattern. Karst landforms such as dolines, uvala and some sinkholes are present mainly on the western slopes of the Mt. Cetona;

   (c) *Montagnola Senese Ridge* (MORms) type area, mostly on metamorphic rocks; steep slopes and very common summit planation surfaces (Figure 6). The drainage density is low and characterised by deep valleys and gorges cutting transversally across the ridge. Hypogenous karst features are common on the marbles; Dolines, uvala and sinkholes are also present.

Figure 4. The landscape of the Chianti Ridge (MORch) from south-west. In evidence on top of the ridge the flat remnants of the Pliocene summit planation surface (indicated by the dashed white line) and the relatively steep mostly forested slopes. In the foreground PLBs landscape.

Figure 5. The landscape of the Cetona Ridge (MORcr). In the foreground, marked by the white dashed line, the evident summit planated surface and in the background the rising relief of the Mt. Cetona To the left the occurrence of Pliocene sandstones marks the occurrence of PLBs landscape.

2. **Landscapes of the Ligurian Complex (LIL)** - steep to gentle slopes, mostly undulating and widely affected by landslides and DSGM (Figure 7). Local structural landforms and remnants of planation surfaces are locally preserved; strong water induced soil erosion processes; dominant arable land.

3. **Landscapes of the Miocene Continental and Marine Basins (MIB)** - gentle to steep hilly morphology. It is further subdivided into:

   (a) *Casino Basin-type landscape* (MIBc) modelled on gravelly, sandy and clayey sediments; moderately steep and stepped slopes, frequent landslides and strong soil erosion processes, land use mostly arable and permanent crops (Figure 6).

   (b) *Grotti-type landscape* (MIBg) modelled on calcareous breccias and conglomerates, steep mostly forested slopes and frequent doline and sinkholes.

Figure 6. In the background the Montagnola Senese Ridge (MORms) from the west. In evidence the flat summit planation surfaces and the mostly forested slopes. In the foreground the gentle Casino Basin-type landscape (MIBc) modelled on Miocene clays, sand and conglomerates. The arable lands correspond to the softer terrains while the steeper escarpments, due to selective erosion, are forested.

Figure 7. Widespread gravitational phenomena affecting the irregular slopes modelled on the Ligurian Complex (LIL). In the background the volcanic dome of the Middle Plesitocene Mt. Amiata and the flat surfaces of the lava flows (VOL).

4. **Landscape of the Pliocene Marine Basins (PLB)** - gentle slopes, mostly arable lands with permanent crops. They are subdivided into:

   (a) *Siena-type landscape* (PLBs) on sandy dominated rocks, selective erosion is dominant with stepped slopes commonly affected by rotational slides and small earthflows. Wide almost flat structural and sub-structural summit surfaces (Figure 8).

   (b) *Val D'Orcia-type* (PLBc) landscape on clay dominated rocks, gentle slopes severely affected by soil erosion processes and widespread earth- and mudflows. Widespread badlands and biancane (Figure 9) are disappearing mainly due to mechanical agriculture (Figure 10) and pasture abandonment.

5. **Landscapes of the Mt. Amiata Volcano (VOL)** - steep forested slopes of the volcanic dome and flat and gently dipping surfaces of the lava flows (Figure 7). Steep escarpments due to selective erosion and landsliding at their outer margins including DSGMs (Coltorti et al., 2011). To the south-east of the Mt. Amiata is also found the residual neck of the older Radicofani volcano (Barberi et al., 1994).

Figure 8. The Siena-type landscape (PLBs) to the northeast of Siena characterised by selective erosion forested escarpments modelled on sands and conglomerates and gently dipping summit structural surfaces.

6. **Karstic Landscapes (KAL)** - Karstic dominated landscapes, arable lands and permanent crops:
   (a) *Landscape of the calcareous tufa and travertines (hot spring)* (KALt) (Figure 11), almost flat surfaces bounded by stepped slopes or steep escarpments following former waterfalls and pools; local mounds and fissure ridges along hot springs (i.e. Rapolano, Sarteano);
   (b) *Landscape of the polje's* (KALp) located at the edges of the limestone dominated ridges; they are wide flat plains occupied by lakes and swamps artificially drained during historic times (i.e. Pian del Lago, Piano di Rosia). They are filled with reddish polygenic sediments (fluvial, lacustrine, colluvial, relict and polygenic paleosoils).
7. **Landscapes of the Arable Valley Bottoms (VAL)**, subdivided into:
   (a) *Landscapes of the inner valleys* (VALi), flat alluvial plains with entrenched active channels and up to 4 orders of hanging alluvial terraces (Figure 12) (i.e. Orcia and Ombrone river)
   (b) *Landscape of the Valdichiana* (VALv), flat plains definitively reclaimed at the end of the 19thth century by means of an artificial hanging channel network and sediment traps (Alexander, 1984).

Figure 9. Typical hilly landscape on the Pliocene marine clays (PLBc) with local remnants of the biancane's and badlands dominated cultural landscape (north of Pienza).

Figure 10. An autumn view of the Val D'Orcia type landscape (PLBc), UNESCO's World Heritage site. In evidence the intensively farmed arable land that has removed badlands and biancane landforms. The town on top of the hill is Pienza located on an almost flat structural surface modelled on sands and conglomerates (PLBs) on top of the clays (PLBc).

5. Conclusions

The 1:200,000 geomorphological map of the Province of Siena presents seven major landscape systems dominated by different geomorphological processes. The mainly expert based analysis started from a 1:25,000 geomorphological map of the whole area. In order to provide a small scale geomorphological map we generalized the geomorphological complexity and variability analyzing the statistical occurrence and mutual relationships between the main geomorphological processes responsible for the landscape modeling. In the area they are: 1) selective erosion, driven by bedrock characteristics; 2) gravity, mostly driven by bedrock characteristics concerning slope steepness, length

and shape, landslide typology and related geometries; 3) running water and related soil erosion, mainly driven by bedrock characteristics in terms of water infiltration capability. In addition we took into consideration land use, clearly related to bedrock characteristics concerning the distribution of mainly arable and forested lands, the former first mostly located on less resistant lithologies and the latter on more resistant lithologies.

The landscape of Siena Province is therefore mostly related to the complex geological setting including bedrock typologies with differential response to erosion. Steeper slopes are found on more resistant lithologies. From the Miocene to Middle Pliocene the area underwent complex climatically induced marine transgressions and regressions (Bossio et al., 1998; Pascucci et al., 1999; 2008; Capezzuoli et al., 2003). Tectonics generated synforms and antiforms, the former hosting the main sedimentary depocenters (Coltorti and Pieruccini, 1997; Bossio et al., 1998; Brogi, 2011). Widespread planation processes occurred during the Middle Pliocene and affected both antiforms and synforms generating flat erosional surfaces (Coltorti and Pieruccini, 2002). After the Middle Pliocene, vertical uplift was responsible for the evolution of the present day drainage pattern (Coltorti and Pieruccini, 1997; Bossio et al., 1998). Denudation and downcutting were more effective within the Mio-Pliocene basins made of softer terrains. Most of the landscape is therefore related to the re-exhumation of old structural elements and to selective erosion. Very short volcanic activity at the end of Middle Pleistocene created Mt. Amiata, the highest relief of the province (Ferrari et al., 1996). During the deepening of the drainage network, river terraces and large bodies of travertine and calcareous tufa were deposited (Capezzuoli and Sandrelli, 2004), the latter usually located at the border of the limestone ridges where deeper aquifers spring out. Brogi et al. (2005) suggest a neotectonic origin for the hot springs although the absence of lateral continuity of the structure may indicate water rising along the old and inactive fractures and faults. Finally, intensive land use led to the creation of the typical badlands and biancane that characterized most of the landscapes of the basins while woodlands and forests are confined to the harder bedrock of the mountain ridges. The 1:200,000 scale geomorphological map can therefore be used as a tool for local government awareness and land management (i.e. soil erosion) but also to produce susceptibility maps (i.e. landslides, flooding) or for purposes of landscape evaluation and valorisation.

Software

The geomorphological database has been managed in ESRI ArcGIS 9.3 as well as the DTM used for the creation of an 'hillshade' raster. The maps and the reference grids have been exported as PNG files and imported in to Macromedia Freehand 10 for the cartographic rendering in a single layout and legend editing.

Figure 11. The travertine fissure ridge at Rapolano Terme (KALt). Today the travertine is still forming only along limited reaches of the fissure.

Figure 12. The Ombrone River from the north (VALi). The black arrows on the right side indicate four orders of alluvial terraces.

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References

ALEXANDER, D. (1984) The Reclamation of Val-di-Chiana (Tuscany), Annals of the Association of American Geographers, 74, 527–550.

BARBERI, F., BUONASORTE, G., CIONI, R., FIORDELISI, A., FORESI, L., IACCARINO, S., LAURENZI, M., SBRANA, A., VERNIA, L. and VILLA, I. (1994) Plio-Pleistocene geological evolution of the geothermal area of Tuscany and Latium, Memorie Descrittive della Carta Geologica d'Italia, XLX, 77–134.

BOSCATO, P., COLTORTI, M. and REGGIANI, P. (2008) Pliocene Anancus arvernensis (Croizet & Jobert, 1828) remains from Cetona (Siena): stratigraphy, chronology and paleoenvironment., Bollettino della Società Geologica Italiana, 127(1), 151–162.

BOSSIO, A., COSTANTINI, A., FORESI, L., LAZZAROTTO, A., MAZZANTI, R., MAZZEI, R., PASCUCCI, V., SALVATORINI, G., SANDRELLI, F. and TERZUOLI, A. (1998) Neogene-Quaternary sedimentary evolution in the western side of the Northern Apennines (Italy), Memorie Società Geologica Italiana, 52, 513–525.

BOSSIO, A., MAZZANTI, R., MAZZEI, R., SALVATORINI, G. and SANDRELLI, F. (1992) Il Pliocene del Bacino di Chiusdino, Atti Società Toscana di Scienze Naturali, Memorie Serie A, 98, 193–250.

BOSSIO, A., MAZZEI, R., SALVATORINI, G. and SANDRELLI, F. (2002) Geologia dell'area compresa tra Siena e Poggibonsi ('Bacino del Casino'), Atti Società Toscana di Scienze Naturali, Memorie, Serie A, 107, 69–86.

BROGI, A. (2011) Bowl-shaped basin related to low-angle detachment during continental extension: The case of the controversial Neogene Siena Basin (central Italy, Northern Apennines), Tectonophysics, 499(1-4), 54–76.

BROGI, A., CAPEZZUOLI, E., COSTANTINI, A., GANDIN, A. and LAZZAROTTO, A. (2005) Tectonics and travertines relationship in the Rapolano Terme area (Northern Apennines, Italy), In OZKUL, M., YAGIZ, S. and JONES, B., (eds.) Proceedings of Ist International Symposium on Travertine, 21-25/09/2005, Pamukkale University, Denizli (Tr), Kozan Ofset, Ankara, pp. 149–154.

CAPEZZUOLI, E., FORESI, L., G.SALVATORINI and SANDRELLI, F. (2003) Nuovi dati sulla sedimentazione del Pliocene medio nel settore sud-occidentale della Valdelsa (Provincia di Siena), Geo-Acta, Special Issue, 2, 42–45.

CAPEZZUOLI, E. and SANDRELLI, F. (2004) I sedimenti quaternari del settore meridionale della Valdelsa (Provincia di Siena), Il Quaternario, 17(1), 33–40.

CILLA, M., COLTORTI, M., FARABOLLINI, P., DRAMIS, F., GENTILI, B. and PAMBIANCHI, G. (1996) Fluvial sedimentation in the Early Holocene in the Marchean Valley (Central Italy), Il Quaternario, 9(2), 459–464.

COLTORTI, M., BROGI, A., FABBRINI, L., FIRUZABADI', D. and PIERANNI, L. (2011) The sagging deep-seated gravitational movements on the eastern side of Mt. Amiata (Tuscany, Italy), Natural Hazards, DOI 10.1007/s11069-011-9746-3, 191–208.

COLTORTI, M. and PIERUCCINI, P. (1997) Middle-Upper Pliocene 'Compression' and Middle Pleistocene 'Extension' in the East Tiber Basin: from 'synform' to 'extensional' basins in the Tyrrhenian side of the northern Apennines, Il Quaternario, 10(2), 521–528.

COLTORTI, M. and PIERUCCINI, P. (2002) The late Lower Pliocene Planation surface and mountain building of the Apennines (Italy), Studi Geologici Camerti, Special Volume 'Large-scale vertical movements and related processes', 1, 45–60.

COLTORTI, M., RAVANI, S. and VERRAZZANI, F. (2007) The growth of the Chianti Ridge: progressive unconformities and depositional sequences in the S. Barbara Basin (Upper Valdarno, Italy), Il Quaternario, 20, 1-2, 67–84.

EUROPEAN COMMISSION (1994) CORINE Land Cover Technical guide, EUR12585 EN, OPOCE, Luxembourg, 163 pp.

FERRARI, L., CONTICELLI, S., BURLAMACCHI, L. and MANETTI, P. (1996) Volcanological evolution of the Monte Amiata, Southern Tuscany: new geological and petrochemical data, Acta Vulcanologica, 8, 41–56.

GEOLOGICAL SURVEY OF ITALY (1994) The 1:50,000 scale geomorphological maps of Italy, survey guidelines, .

GOUDIE, A., VILES, H. and PENTECOST, A. (1993) The late Holocene tufa decline in Europe, The Holocene, 3(2), 181–186.

GUASPARRI, G. (1978) Calanchi e biancane nel territorio senese: studio geomorfologico, L'Universo, LVIII(1), 97–140.

LIOTTA, D. and SALVATORINI, G. F. (1994) Evoluzione sedimentaria e tettonica della parte centro-meridionale del bacino pliocenico di Radicofani, Studi Geologici Camerti, Volume Speciale, 1, 65–77.

MACKANESS, W., RUAS, A. and SARJAKOSKI, L. (2007) Generalisation of Geographic Information: Cartographic Modelling and Applications, Oxford, Elsevier, 386 pp.

PASCUCCI, V., COSTANTINI, A., MARTINI, I. and DRINGOLI, R. (2008) Tectono-sedimentary analysis of a complex, extensional, Neogene basin formed on thrust-faulted, Northern Apennines hinterland: Radicofani Basin, Italy, Sedimentary Geology, 183(1-2), 71–97.

PASCUCCI, V., MERLINI, S. and MARTINI, I. (1999) Seismic stratigraphy of the Miocene-Pleistocene sedimentary basins of the Northern Tyrrhenian Sea and Western Tuscany (Italy), Basin Research, 11, 337–356.

PASSERINI, P. (1964) Il Monte Cetona., Bollettino della Società Geologica Italiana, 83, 219–338.

REGIONE TOSCANA WEB SITE (2011) Sviluppo e gestione del Continuum Territoriale Geologico [Online]. Available from: http://www.regione.toscana.it/regione/export/RT/sito-RT/Contenuti/sezioni/territorio/cartografia/rubriche/documentazione/visualizza_asset.html_1935162879.html, [Last accessed: 10 October, 2011].

RIFORGIATO, F., FORESI, L., MAZZEI, R., SALVATORINI, G. and SANDRELLI, F. (2005) Chronostratigraphic revision of some Pliocene basins in Tuscany at the Zanclean/Piacenzian boundary, Bollettino della Società Geologica Italiana, 3, 7–13.

SMIRNOFF, A., PARADIS, S. and BOIVIN, R. (2008) Generalizing surficial geological maps for scale change: ArcGIS tools vs. cellular automata model, Computer and Geosciences, 34(11), 1550–1568.

VITTORINI, S. (1977) Osservazioni sull'origine e sul ruolo di due forme di erosione nelle argille: calanchi e biancane, Bollettino Società Geografica Italiana, 6, 25–54.

GEOMORPHOLOGICAL MAP AND LAND UNITS AT 1:200.000 SCALE OF THE SIENA PROVINCE (SOUTHERN TUSCANY, ITALY)

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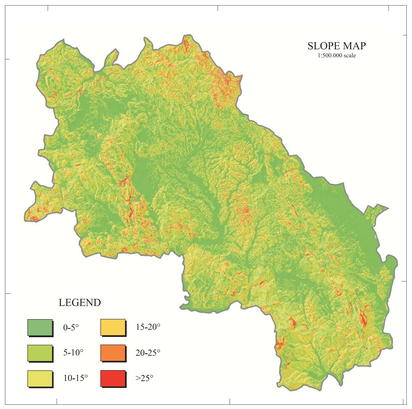
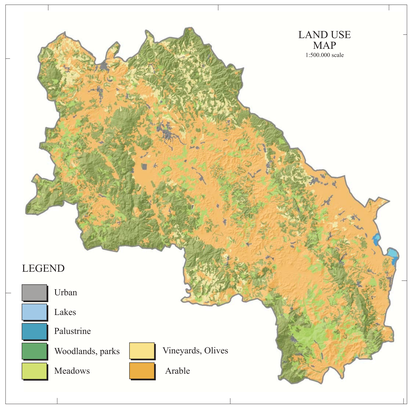




LEGEND

LANDSCAPES OF THE MOUNTAIN RIDGES

MORch — Chianti Ridge type area
Landscapes on sandstones and marly limestones; steep and locally stepped slopes, forested, arable and permanent croplands, few remnants of summit planation surfaces; relatively dense drainage network, linear to dendritic with deep valleys and gorges.

MORcr — Cetona-Rapolano Ridge type area
Landscapes on limestones and marly limestones; steep and short mostly forested slopes, planated summit surfaces; small catchments and low density drainage network, mainlyswith linear pattern; karst landforms, dolines, uvala and sinkholes mainly along the slopes of the Cetona Mt.

MORms — Montagnola Senese Ridge type area
Landscapes on mainly metamorphic rocks; steep forested slopes and planated summit surfaces, low drainage density with deep valleys and gorges cutting transversally the ridge; hypogenous karst features on marbles.

LANDSCAPES OF THE LIGURIAN COMPLEX

LIL — Steep to gentle mostly undulated slopes, mainly arable lands widely affected by landslides and Deep Seated Gravitational Movements, strong runoff soil erosion processes, local remnants of summit planation surfaces.

LANDSCAPES OF THE MIOCENE CONTINENTAL AND MARINE BASINS

MIBc — Casino Basin type area
Landscapes on gravelly, sandy and clayey sediments; mostly arable and permanent crops, steep and stepped slopes, frequent landslides and strong soil erosion processes.

MIBg — Grotti type area
Landscapes on calcareous breccias and conglomerates, steep mostly forested slopes and frequent doline and sinkholes.

LANDSCAPES OF THE PLIOCENE MARINE AND TRANSITIONAL BASINS

PLBs — Siena type area
Landscapes on sandy dominated rocks, mostly permanent crops and arable lands, wide almost flat structural and sub-structural summit surfaces and selective erosion stepped slopes affected by rotational slides and small earthflows.

PLBc — Valdorcia type area
Landscapes on clay dominated rocks, gentle arable slopes severely affected by soil erosion processes and widespread earth- and mudflows; badlands and biancane recently disappearing mainly due to mechanical agriculture and pasture abandonment.

LANDSCAPES OF THE MT. AMIATA VOLCANO

VOL — Steep forested slopes of the volcanic dome and flat and gently dipping surfaces of the lava flows; steep selective erosion escarpments affected by landslides and Deep Seated Grvavitational Movements

KARSTIC LANDSCAPES

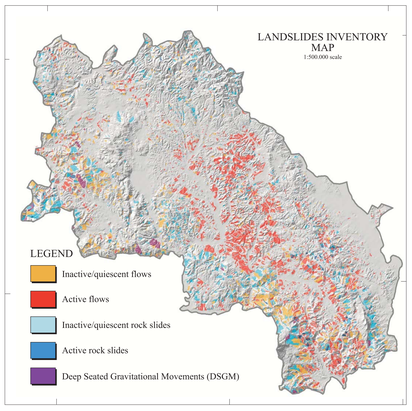
KALt — Landscapes of travertines (hot springs) and calcareous tufa
Flat and undulated arable surfaces bounded by stepped slopes or steep escarpments following former waterfalls and pools; local mounds and fissure ridges along old hot springs (i.e. Rapolano, Sarteano).

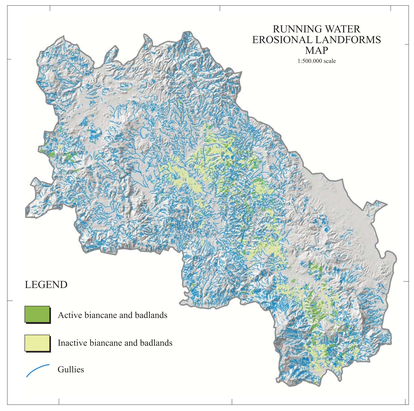
KALp — Landscapes of the polje's
Wide flat arable plains occupied by lakes and swamps artificially drained in historical times (i.e. Pian del Lago, Piano di Rosia) filled with reddish polygenic sediments (fluvial, lacustrine, colluvial, relict and polygenic paleosoils).

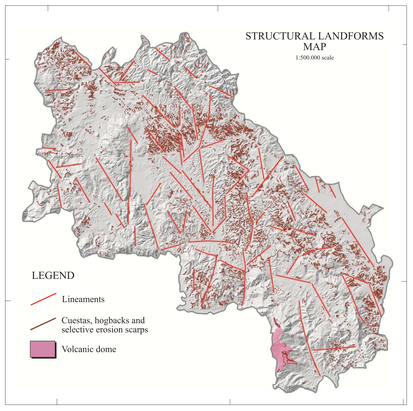
LANDSCAPES OF THE ARABLE VALLEY BOTTOMS

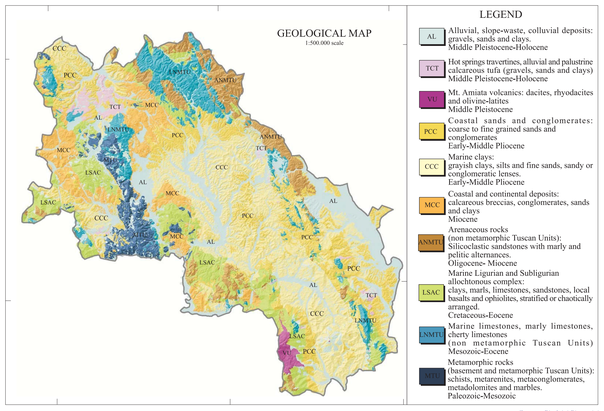
VALi — Landscapes of the inner valleys
Flat arable alluvial plains with entrenched active channels and up to 4 orders of hanging alluvial terraces.

VALv — Landscapes of the reclaimed Valdichiana
Flat arable plains definitively reclaimed at the end of the XIX century with artificial hanging channels network and sediment traps









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