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Ophiolite complex of Piedmont-Ligurian basin (Northern Apennines)

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The Northern Apennines contain remnants of the Piedmont-Ligurian Basin (PLB) or ocean, which during the Late Mesozoic time (mainly in the Jurassic) separated the paleo-Europe (Iberian plate) from the southern paleocontinent Adria at the Africa promontory. The closure of the PLB and subsequent collision of Europe/Adria in Cretaceous-Cenozoic time led to the exhumation of the ophiolite complex of Northern Apennines in the Ligurian units. The paper gives information obtained by the authors during several field trips on the composition of the ophiolite complex of the Northern Apennines, representative of the composition and structure of the oceanic lithosphere. The latter, absent in the territory of Ukraine, is a key question to understanding the evolution of the oceanic crust, subduction processes, and formation of accretion wedges in the transitional zones to the continents. The Ligurian ophiolites of the PLB constitute an accessible and unique window to track the opening and evolution of the slow-spreading oceanic lithosphere. The Internal Ligurian ophiolites consist of km-scale gabbroic bodies intruded into depleted mantle peridotites and bear remarkable structural and compositional similarities to oceanic lithosphere from slow and ultra-slow spreading ridges. The External Ligurian ophiolites, associated with continental crust material and transition zone between the oceanic and continental crust, include mantle sequences retaining a subcontinental lithospheric origin. The gabbro-peridotite associations from the Internal Ligurian ophiolites were explored in the Bracco-Levanto ophiolite massif, which includes a km-scale gabbroic body, recalling the oceanic core complexes from modern spreading centres, intruded into the mantle peridotites. The peridotites and the gabbros from these ophiolites record a composite history involving deformation and alteration from high temperature to seafloor conditions. The top of the peridotites is covered by tectono-hydrothermal breccias (ophicalcites), radiolarites, and sedimentary breccias that testify to the exposure of peridotites at the seafloor. This succession is then covered by basalts pillow-lavas. Thus, the almost full section of the ophiolite complex is represented here.

Key words: Northern Apennines, Piedmont-Ligurian basin, Ligurides, ophiolites, peridotites, accretion wedge (prism).

Introduction. The oceanic crust and upper mantle (ophiolite complex), their composition and origin, draw much attention from many geologists and geophysicists. In the Northern Apennines, the ophiolite complex of the Piedmont-Ligurian Basin is now exposed on the surface, providing new knowledge on the origination and evolution of the oceanic crust, rifting and drifting processes, and formation of the continental margins. During

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the research grant for Ukrainian scientists at Parma University (Department of Life Sciences and Environmental Sustainability), the paper's authors participated in the geological excursions in the Northern Apennines and Southern Alps conducted by Professors A. Artoni and A. Montanini.

The Northern Apennine (Fig. 1) collisional belt records the long-lived tectonic history of convergence between the Europe and Adria plates, active since the Late Cretaceous. It consists of a number of tectonic units arranged in an accretionary wedge. The rear Ligurian Units represent the oceanic basin's magmatic base and sedimentary cover. The Ligurian Units of the Northern Apennines are characterized, in fact, by a complex tectonic evolution derived from the interference, in space and time, of predominantly «Alpine» and «Apennine» deformations having west and east vergence, respectively.

In the Northern Apennines, the rocks of the ophiolitic complex of Ligurian Units are exposed at the surface. They are remnants of the oceanic crust of the Piedmont-Ligurian basin (PLB) or ocean (or Alpine Tethys ether Ligurian Tethys), which during the Late Mesozoic separated paleo-Europe (Europe-Iberia plate) from the southern paleocontinent Adria/Apulia at the Africa promontory [Argand, 1924; Elter, 1975; Stampfli et al., 1998; Manatschal, Bernoulli, 1999]. The closure of the PLB during the Cretaceous to Eocene and the following Oligocene/Miocene Europe/Adria collision characterized the evolution of the Alps and the early stages of evolution of the Apennines [Elter, 1975; Laubscher, 1991; Doglioni, 1991; Rosenbaum, Lister, 2004; Schettino, Turco, 2006]. This narrow arc-shaped basin in Late Lurassic — Late Cretaceous time extended in the NE direction within the Carpathian-Pannonian region, forming the Carpathian Basin (Fig. 2) [Schmid et al., 2004]. Thus, we should have in the Ukrainian Carpathians the remnants of the closure of the PLB, despite ophiolite complexes and radiolariteslithologies that are rather diagnostic for the PLB not being found in the northern branch of Alpine Tethys, in particular on the territory of Ukraine [Schmid et al., 2004].

Fig. 1. Simplified scheme of the circum-Mediterranean collisional belt [Marroni et al., 2019] and location of the study region (black rectangle).

Regional setting and tectonic overview. The northern sector of the Apennines was formed by closing the narrow PLB. The opening of the latter in Jurassic time between the Adria plate (northern African promontory) and Iberia (proto-Europe) was caused by the opening of the Central Atlantic on the transform fault [Pini, 1999; Marroni et al., 2019]. There is now a consensus on a belt evolution through two diachronous oppositely dipping subductions: a Late Cretaceous — Middle Eocene east-dipping «Alpine» subduction, and a Late Eocene — present west-dipping «Apennine» subduction [Doglioni, 1991; Molli et al., 2010; Marroni et al., 2017]. The result is a fold-and-thrust belt of E- to NE-verging structural units, with the Ligurian Units at the top of the tectonic pile, thrust over the Subligurian and Tuscan Units (Fig. 3). That caused the preservation in the Northern Apennines the remnants of the PLB and its transition to the Adriatic continental margin (Fig. 3, 4). The Liguride units are recognized in two different lithostratigraphic and tectonic settings, corresponding to the Internal Liguride (IL) and External Liguride (EL) units [Elter, 1975]. Whereas the IL units are representative of the oceanic sector of the PLB, the EL units are interpreted as derived from the domain that joined the oceanic areas of PLB to the Adriatic plate continental margin.

The successions of the IL units include an ophiolite sequence represented by mantle ultramafics and gabbros covered by basalt lavas and sedimentary ophiolite breccias [Decandia, Elter, 1972; Abbate et al., 1980]. These remnants of the embryonic oceanic lithosphere are commonly interpreted to have formed at magma-poor ocean-continent transitions similar to the Iberia-Newfoundlands margins [Manatschal, Muntener, 2009]. Some of the ophiolites from the Alpine-Apennine belt bear remarkable structural and compositional similarities to oceanic lithosphere from slow and ultra-slow spreading ridges [Lagabrielle, Cannat, 1990; Tribuzio et al., 1999; Sanfilippo, Tribuzio, 2011].

In the **EL units**, the ophiolites are associated with rocks of continental origin. These ophiolites occur in the oldest succession of the EL that consists of Upper Cretaceous sedimentary melanges typically characterized

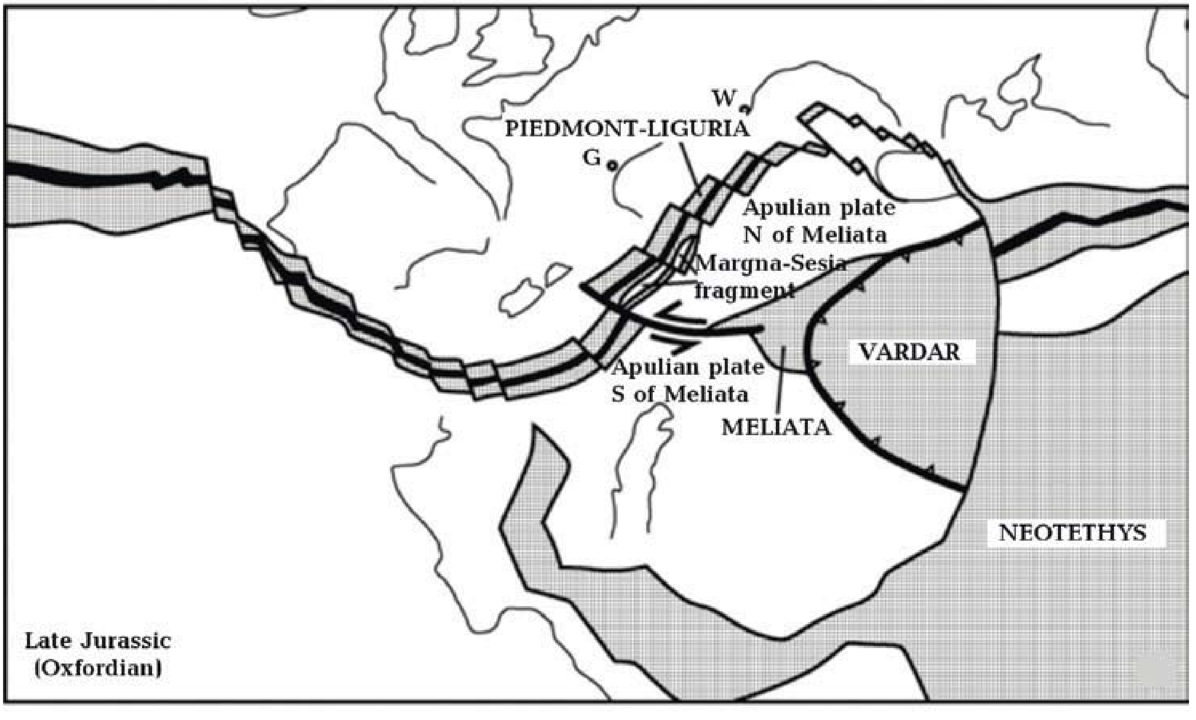

Fig. 2. Large-scale paleogeographical reconstruction for Late Jurassic [Schmid et al., 2004].

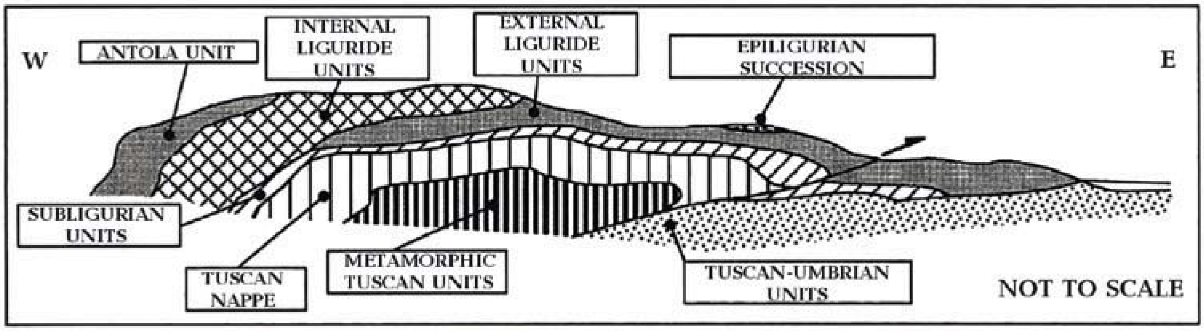

Fig. 3. Schematic cross-section of the Northern Apennines (from [Elter, 1975]).The fragments of the Piedmont-Ligurian oceanic basin are represented by the Ligurides units at the top of the tectonic pile. The Ligurides associate with two different lithostratigraphic units — Internal Liguride, related to Ligurie-Piedmonte oceanic basin, and External Liguride units, representative of transition zone to the Adria continental margin. The Internal Liguride units are thrust onto the External Liguride units. The Liguridesare overlain by the Epiligurian successions that fill a piggyback basin system. In the Miocene, the Liguride units and the overlying Epiligurian succession were deformed during their thrusting onto the easternmost domain of the Adriatic plate, represented by Subligurian units, Tuscan nappe, metamorphic Tuscan and Umbrian-Tuscan units.

by slide blocks of igneous, metamorphic, and sedimentary rocks of different ages and metamorphic grades [Marroni et al., 2019]. The sedimentary mélange is overlain by Upper Cretaceous carbonate flysch, known in the literature as Helminthoid Flysch. In the Northern Apennines, the IL units are thrust onto the EL units (see Fig. 3).

The Northern Apennines region includes three major geomorphological domains (see Fig. 4): 1) a south-western undersea region of the Ligurian Sea belonging to the PLB; 2) an «S-shaped» mountain range formed by the SW Alps, Ligurian Alps and the northern part of the Apennines; and 3) a north-eastern region that comprises the foredeep Neogene covered by thick sediments of the present Po plain [Molli et al., 2010].

The geology and tectonics of the Northern Apennines are summarized by a geological map of the Northern Apennines at 1:250 000 scale [Conti et al., 2020] and many related publications. The successions outcropping in the Northern Apennines experienced the following tectonic phases, from the oldest:

1) Variscan phases, related to the building of the Variscan chain during the Carboniferous assembling of the Pangea supercontinent;

2) Jurassic extension related to the opening of the PLB;

3) Ligurian phases (Late Cretaceous — Paleogene) that led to the formation of the Ligurian prism;

4) Tuscan phases (Early Miocene) that led to metamorphism and nappe emplacement in the Tuscan Domain;

5) Miocene-Quaternary opening of the Tyrrhenian margin in a back-arc setting.

Our paper concerns mainly the Jurassic and Ligurian tectonic phases during the Jurassic-Paleogene time. Their brief tectonic history and that of the Tuscan phase are given below.

Jurassic extension. Extension, related to the rifting phase that led to the opening of the PLB, started from the Adria continental margin in the Early Jurassic (Sinemurian) as a result of the first opening stages of the central Atlantic Ocean. In the Middle Jurassic, ongoing rifting led to the formation of the Adria and Europe passive continental margins. Rifting was probably asymmetric, with simple shear kinematics along a major detachment dipping below the European margin [Lemoine et al., 1987; Stampfli et al., 1998; Marroni et al., 1998; Manatschal, Bernoulli, 1999; Manatschal, 2004]. This led to the formation of the two continental margins (Europe: upper plate, Adria lower plate) that had two very different stratigraphic evolution during the Jurassic (Fig. 5, *a*). At the end of Middle Jurassic, rifting evolved into spreading, with

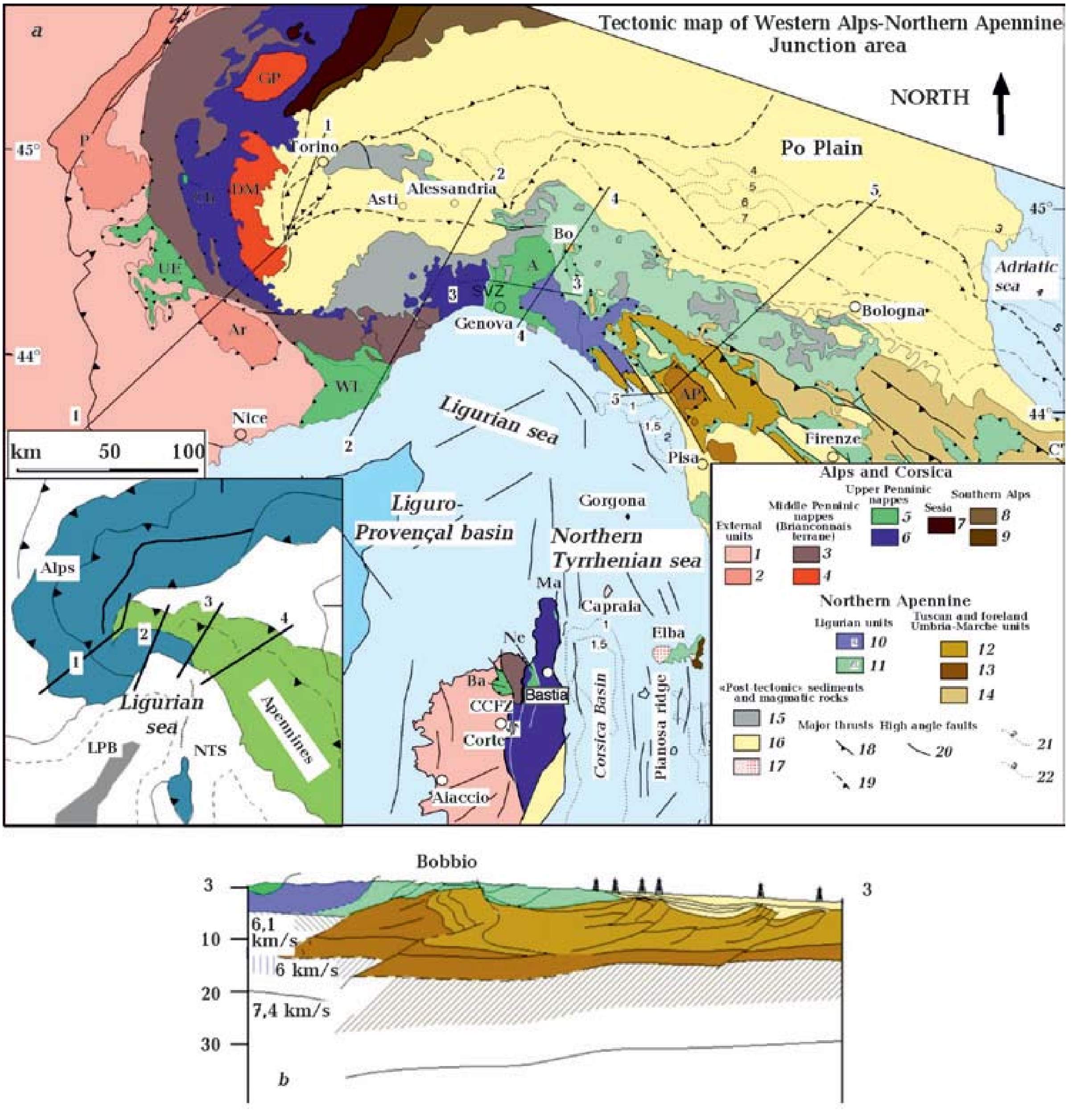

Fig. 4. Tectonic map (*a*) and regional cross-section 3 across the Bobbio window in the Western Alps and Northern Apennine junction area (*b*) [Molli et al., 2010]. The inset shows the regional cross-sections. LPB Liguro-Provençal basin; NTS Northern Tyrrhenian sea.

For the Western Alps: *1*, *2* — Europe-derived external Alpine units (*1* — Alpine foreland units, *2* — External massifs); *3* — Middle Penninic Briançonnais nappes; *4* — Middle Penninic Internal Massif (DM, Dora Maira and GP, Gran Paradiso); *5* — Upper PenninicHelminthoidFlysch. With the same color are also represented the ophiolitic non-metamorphic unit of Chenaillet (Ch) and Sestri Voltaggio Zone (SVZ); *6* — Schistes Lustrés composite nappe system; *7* — Sesia and related units; *8* — Adria lower crust of the Southern Alps (Ivrea); *9* — Adria upper crust basement and cover of the Southern Alps.

For the Northern Apennine: *10* — Internal Ligurian units, IL; *11* — External Ligurian units (EL— and SubLigurian (Canetolo) units; *12*, *13*, *14* — Adria-derived Tuscan and external foreland Umbria-Marche units (*12* — Tuscan nappe, *13* — Tuscan metamorphic units, *14* — Cervarola and Umbria-Marche foreland units); *15* — Post-tectonic cover of Tertiary Piemontese basin and Epiligurian units; *16* — Neogene and Quaternary sediments of Po Plain and inner Tuscany; *17* — Magmatic rocks of Southern Tuscany, volcanic and intrusive bodies; *18* — major thrusts at surface; *19* — major thrusts at subsurface; *20* — high angle normal and transcurrent faults; *21* — sediment thickness in seconds TWTt for the Tyrrhenian Sea; *22* — Pliocene isobaths (in Km) in the Po Plain and Adriatic sea.

formation of the oceanic PLB (Fig. 5, *b*), a slow-spreading mid-ocean ridge system with oceanic lithosphere of reduced thickness, serpentinized mantle peridotites, gabbro bodies, basalts with intercalated sedimentary ophiolitic breccias [Decandia, Elter, 1972; Abbate et al., 1980; Bortolotti et al., 2001]. The Late Jurassic marks the end of spreading in the PLB [Principi et al., 2004].

Ligurian phases. Ligurian phases include the tectonic phases affecting the Ligurian Units from the Late Cretaceous to the Middle Eocene when the closure of the PLB and complete subduction of oceanic crust occurred. It is generally considered that deformation of the Ligurian Units is linked first with a Late Cretaceous — Middle Eocene «Alpine» east dipping oceanic subduction (Fig. 5, *c*) and then with a Late Eocene — Quaternary west dipping «Apenninic» subduction (Fig. 5, *d*) [Doglioni, 1991; Marroni et al., 2017]. The presence of a tectonically active «double-

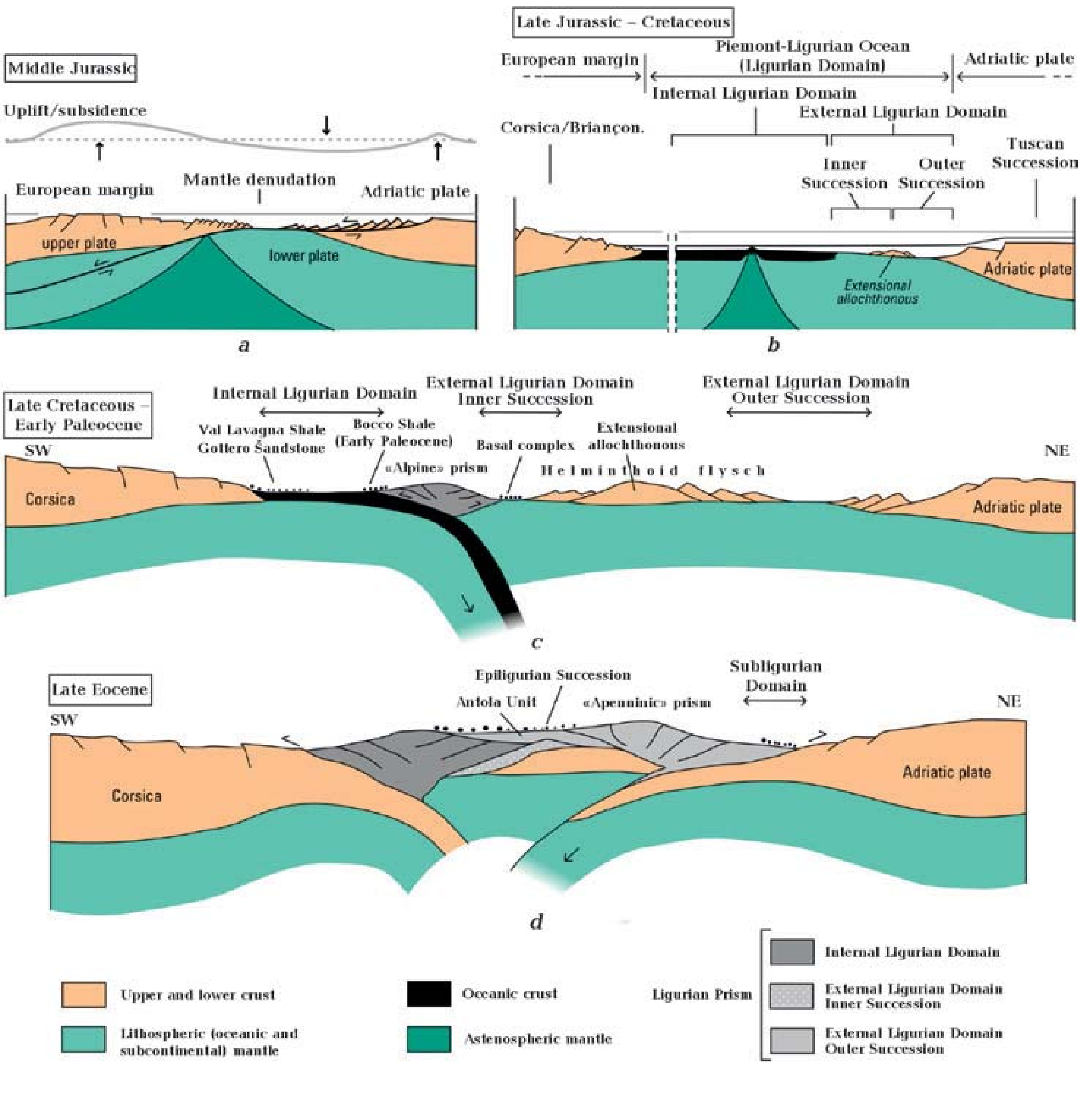

Fig. 5. Tectonic model of opening and subduction of the Piedmont-Ligurian Basin and formation of the complex accretionary prism [Conti et al., 2020]: *a* — mode of asymmetrical extension of continental crust based on Wernicke[1985] and Lemoineet al. [1987] models, *b* — paleogeography of the Piedmont-Ligurian Basin and adjoining areas at the Jurassic—Lower Cretaceous, *c*, *d* — reconstruction of the geodynamic setting and evolution for Late Cretaceous (Campanian—Maastrichtian) and Late Eocene of the Ligurian units of the Northern Apennines.

vergent» accretionary wedge in the Late Cretaceous is testified by debris with ophiolite blocks in the IL domain and in the EL (Inner Succession) (see Fig. 5, *c*). This elevated area that separated the IL and EL successions associates with the accretionary wedge incorporated during this stage mainly material of the oceanic PLB domain.

Ongoing subduction led to the thickening of the accretionary wedge through the continuing incorporation of oceanic crust. The Middle Eocene is usually regarded as the age of the closure of the PLB [Conti et al., 2020]. The end of oceanic crust subduction, closure of the PLB, and inclusion in the accretionary wedge are marked by the deposition of the Epiligurian Succession started at the Middle-Late Eocene. Close to the continental collision, the deformation was transferred eastward, producing an early Apennine orogenic prism with foredeep deposits [Fig. 5, *d*].

Tuscan phases. During the Oligocene-Aquitanian time, ongoing convergence and W-dipping subduction caused foredeep development to affect more external areas of the Adria continental margin, with siliciclastic turbidite deposits of several formations. The Burdigalian (Upper Miocene) marks the inception of the «Tuscan phase», during which the Ligurian prism was emplaced onto the turbidite basins of the Tuscan Domain, leading to the end of sedimentation [Conti et al., 2020]. The successions of the Tuscan Domain were deformed in different tectonic units, originating from several portions of the Adria plate. The underlying unit Tuscan nappes, part of the Apulian (Adria) plate, are exposed in tectonic windows formed during the early stages of deformation in the Northern Apennines [Carmignani et al., 1978]. These tectonic windows, where the Tuscan units crop out, form an arcuate belt along the so-called Tuscan metamorphic ridge (see Fig. 4) [Molli et al., 2010].

One of these tectonic windows — the Bobbio window, considered one of the most significant structures of the northwest Apennine [Molli et al., 2010], is cut by the cross-section 3 (see Fig. 4, *b*). In the Bobbio window, the Tuscan foredeep deposits are exposed below a composite system of Ligurian and Subligurian units. The SW part of the section shows two crustal-scale thrusts. The westernmost thrust, which brings a 6.1—6.0 km/s layer to a depth of 5 km, is connected on the surface with the Subligurian overthrust surface [Molli, 2008]. In general, Fig. 4, *b* represents the thrusting tectonics within the Tuscan Unit, which was overtrusted by Internal Ligurides and Subligurian Units. Along the profile, the Moho gently dips westwards, reaching a depth of ~40 km southwest of the Bobbio, where it rises abruptly to a shallower position (~ 20 km depth) in the Ligurian Basin [Castellarin, 2001].

Ophiolite complex of the Piemont-Liguria basin. As we said before, unit Ligurian nappes comprises oceanic units that paleogeographically belong to the PLB (Alpine Tethys). However, in the Apennines the remnants of this ocean presently form the upper plate in relation to units attributed to the Apulian plate [Laubscher, 1971] (see Fig. 3). This is because the Ligurides (parts of the PLB) were thrust north- and north-eastward onto the Po Plain during Mid-Miocene and later times [Bigi et al., 1990; Finetti et al., 2001].

The successions of the IL units (Fig. 6) include an ophiolite sequence represented by mantle ultramafics and gabbros covered by basalt lavas and sedimentary ophiolite breccias [Decandia, Elter, 1972; Abbate et al., 1980]. Mantle ultramafics, mainly serpentinized lherzolites [Vannucci et al., 1993], are intruded by a Jurassic gabbroic complex formed by low-pressure fractional crystallization of tholeiitic magma [Serri, 1980; Hebert et al., 1989]. The volcanism is represented by normal to transitional MOR pillow-lavas and massive basalts interfingering with radiolarites (cherts) and sedimentary ophiolite breccias [Decandia, Elter, 1972; Abbate et al., 1980]. The sedimentary cover of the ophiolite sequence consists of pelagic, trench, and lower slope deposits ranging in age from Late Jurassic to Early Paleocene (see Fig. 6). The ophiolite sedimentary cover displays the evidence of a pre-Oligocene, polyphase structural evolution associated with a metamorphism ranging from very low grade to blueschists.

This evolution is assumed to represent a deformation history of the IL units developed in an accretionary prism related to a low-rate subduction zone [Marroni, Pandolfi, 1996].

The ophiolites from the IL units, ascribed to a distal portion of the PLB, show no relationship with continental material and include mantle sequences mostly consisting of depleted mantle peridotites [Rampone et al., 1996, 1997; Rampone, Hofmann, 2012], intruded by large-scale MOR-type gabbroic sequences [Principi et al., 2004; Menna, 2009]. Both the EL and IL units bear evidence of polyphase deformation during the orogenesis that led to their elevating and emplacement in the Late Oligocene — Miocene [Marroni et al., 2004].

In the IL units (see Fig. 6), the ophiolite successions crop out as up to 1 km-thick bodies consisting of a basal ophiolite sequence (IL_{of}) with mantle peridotites (serpentinized lherzolites) (Fig. 7) intruded by Jurassic isotropic and layered gabbros (Fig. 8) covered by a Middle Jurassic to Upper Cretaceous basalt-sedimentary sequence [Principi et al., 2004]. The top of the peridotites is covered by tectono-hydrothermal breccias (ophicalcites or cherts) (Fig. 6, 9) and sedimentary breccias that testify to the exposure of peridotites at the seafloor. This succession is then covered by basalts (pillow-lavas) (Fig. 10) [Decandia, Elter, 1972; Abbate et al., 1980; Beccaluva et al., 1984; Cortesogno et al., 1987].

The gabbroic plutons mostly consist of

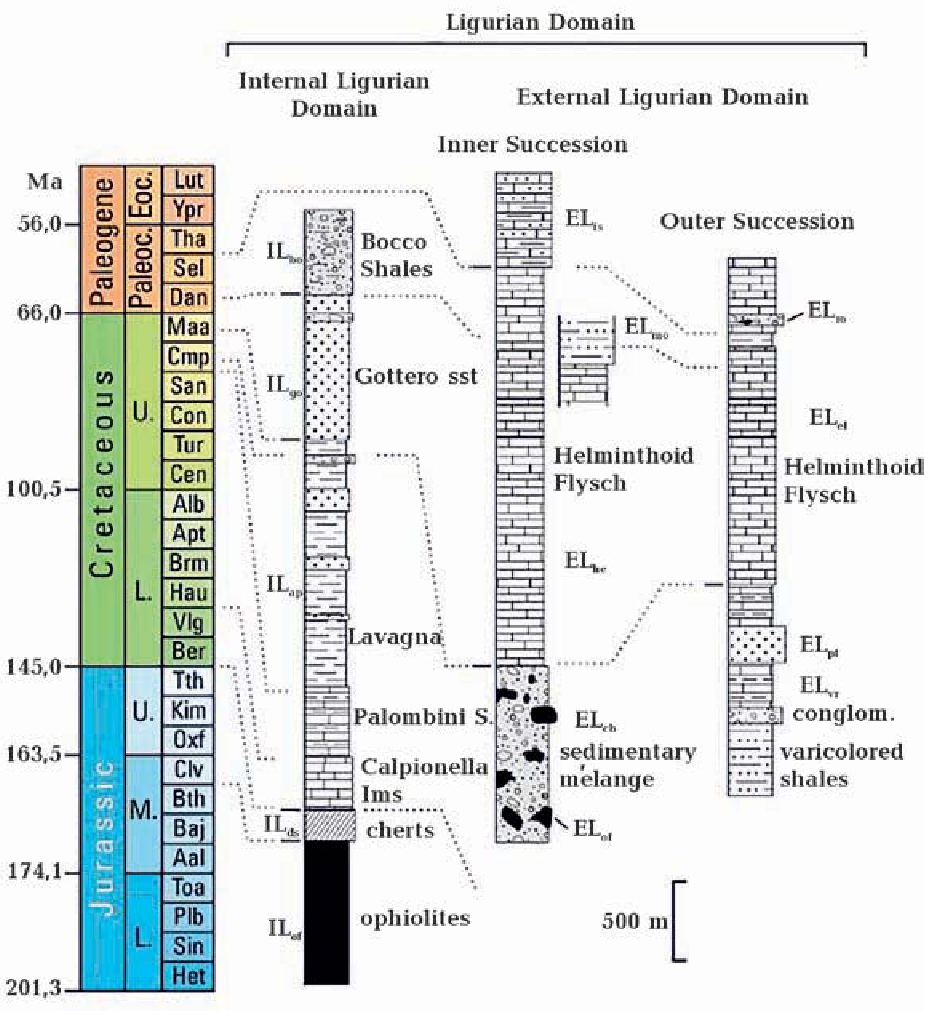

Fig. 6. Stratigraphy of the Ligurian Domain [Conti et al., 2020]. The occurrence of ophiolite-bearing clastic debris is shown in grey.

cliopyroxene-rich gabbros to troctolites, locally interlayered with lenses of olivine-rich troctolites, and show a MORB-type geochemical signature [Tiepolo et al., 1997; Rampone et al., 1998; Tribuzio et al., 2000; Renna, Tribuzio, 2011; Sanfilippo, Tribuzio, 2011]. The mantle

Fig. 7. Peridotites, quarry Piandifieno (*a*), serpentinization of the peridotite, quarry Piandifieno (*b*), serpentinite breccia with dark crystals of spinel and in the green matrix of serpentinite, Bunassola (*c*).

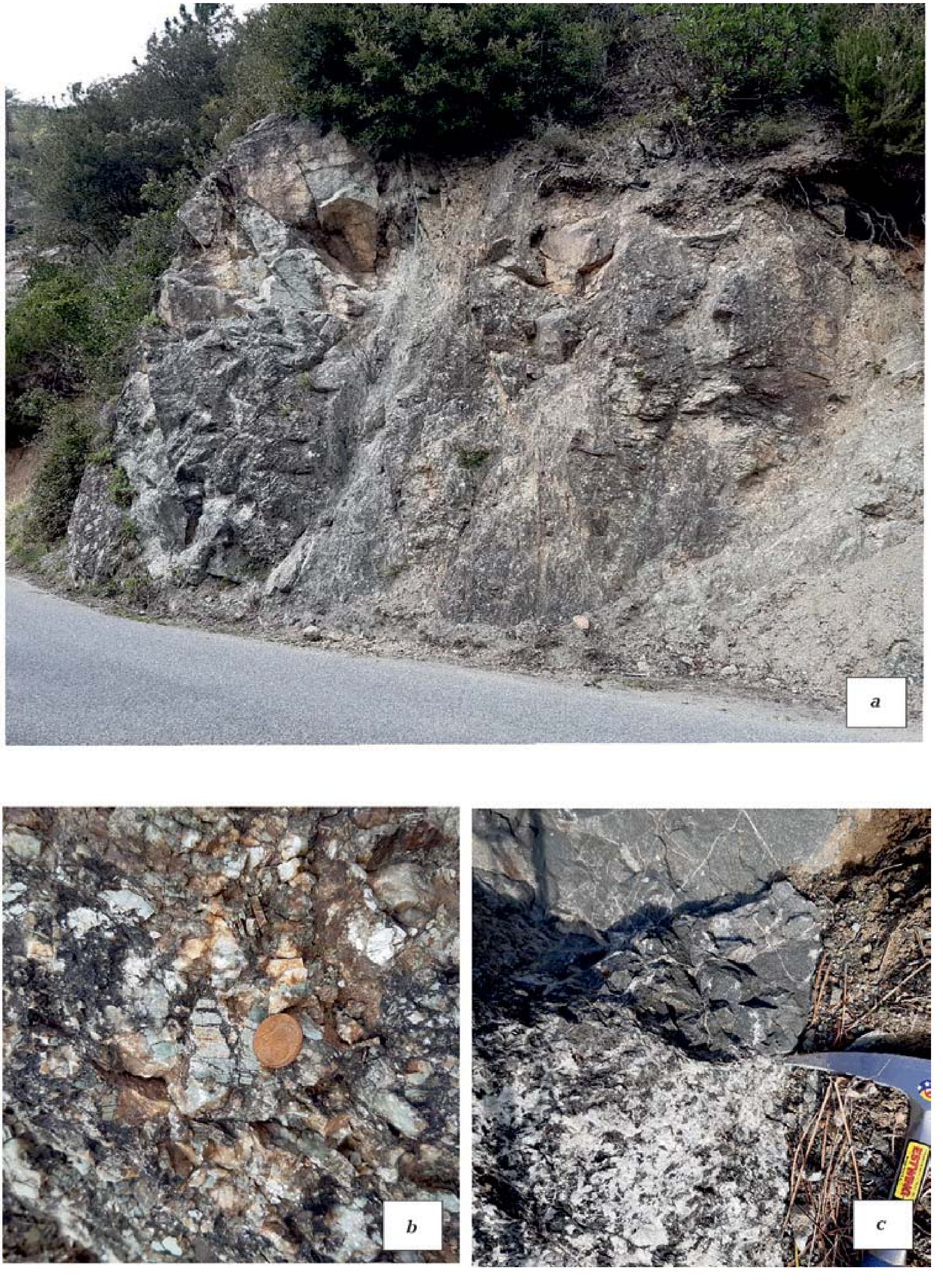

Fig. 8. Gabbro. Massive gabbro, quarry Piandifieno (*a*), contact of coarse-grained gabbro and basalt dike, Bracco (*b*), coarse-grained pegmatoidgabbro with crystals of clinopiroxene, Bracco (*c*).

Fig. 9. Opficalciti (hydrothermal tectonic breccia), Montaretto (*a*), and radiolarites (cherts), Piandifieno (*b*).

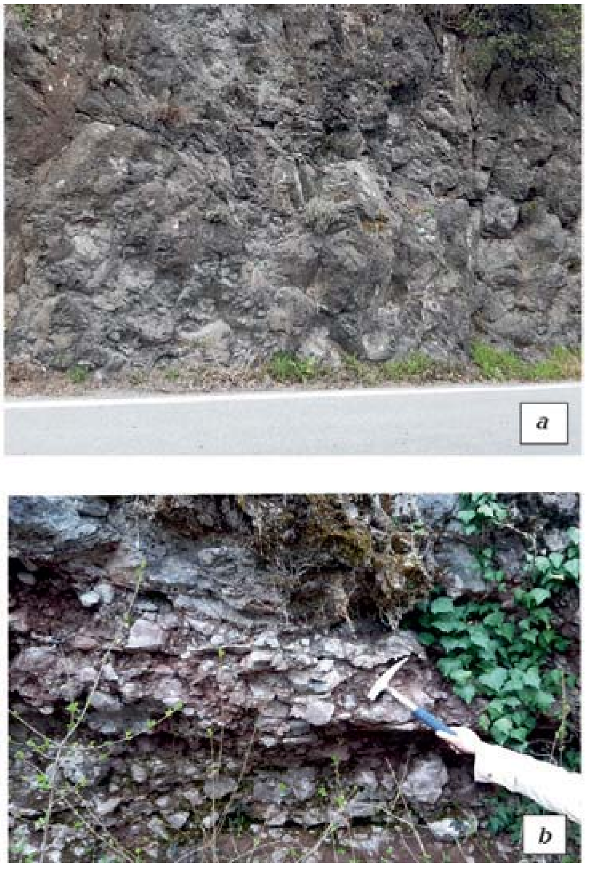

Fig. 10. Pillow basalt flow, Piandifieno (*a*), and basalt breccia, Bergotto (*b*).

sequences, consisting mainly of depleted spinellherzolites, represent either asthenospheric material that ascended in response to oceanic spreading or subcontinental mantle that experienced thermochemical erosion by the upwelling asthenosphere during rifting [Sanfilippo, Tribuzio, 2011; Rampone, Hofmann, 2012].

The ophiolitic complex is exposed in several tightly located bodies over the Ligurian coast near c. Specia. The Bracco-Levanto ophiolite body (Fig. 11) is one of them that occurred within the IL. It represents a body slightly elongated in the NS direction, located between the Bracco and Levanto localities. The Bracco-Levanto ophiolite body provides evidence of a morphological high in the PLB. This paleo-morphological high consists of a gabbroic sequence, and bears close compositional and structural resemblances to the sequences from modern oceanic core complexes of the Mid-Atlantic Ridge, such as the Atlantis Massif at the Central Atlantic [Blackman et al., 2006, 2011]. Figs. 7—10 picture the main rocks of the Bracco-Levanto ophiolite body, made by the authors of the article.

The sedimentary cover of the ophiolite sequence starts with pelagic deposits represented by radiolarites (cherts) (Fig. 9, *b*) and marls Callovian to Tithonian in age (see Fig. 6), the cherts (radiolarites) derived from pelagic siliceous ooze reworked by oceanic bottom currents.

Up section pelagic shales, marlstones, and limestones follow (Calpionella Limestones and Palombini Shales in Fig. 6) and derive

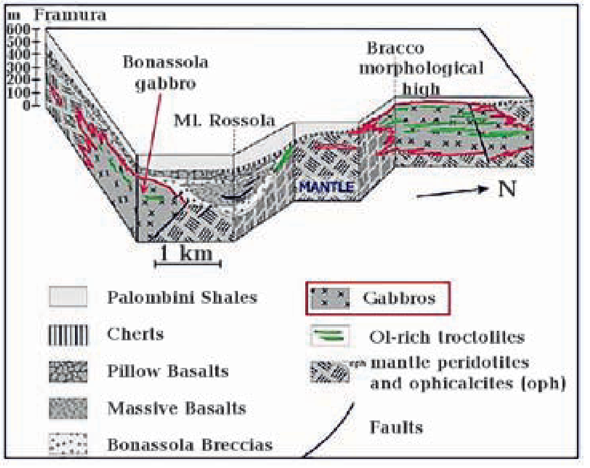

Fig. 11. Schematic reconstruction of the Bracco-Levanto ophiolite body (Internal Ligurian units) in the Upper Jurassic—Lower Cretaceous [Principi et al., 2004].

Fig. 12. External Ligurides: Sedimentary melange (Casanova Formation (*a*)), Bergotto; Helmintoidflysch (*b*), Roccamurata.

from distal carbonate and mixed siliciclastic-carbonate turbidites and pelagites that grade upward in a thick turbiditic succession of mainly siliciclastic composition; the whole succession is Cretaceous in age. During the Late Cretaceous — Earliest Paleocene, coarse-grained sandstone siliciclastic turbidites are deposited at the proximal portion of deep-water fan system developed at the foot of the European continental margin at the transition with the ocean basin. This produces a thick succession of alternating arkoses, sandstones, and shales (Gottero Sandstones in Fig. 6) [Marini, 1991; Pandolfi, 1996; Fonnesu, Felletti, 2019].

The youngest rocks (Late Cretaceous—Paleocene) of the Internal Ligurian Domain are trench deposits represented by thin-bedded turbidites interbedded with ophiolite-bearing slide and debris flows (Bocco Shale in Fig. 6) interpreted as developed from reworking of oceanic lithosphere and its sedimentary cover already incorporated in a Cretaceous accretionary wedge [Marroni, Pandolfi, 2001; Marroni et al., 2017].

In the EL units, ophiolite bodies occur as slide blocks (up to km-scale [Marroni et al., 1998]) within Upper Cretaceous sedimentary melanges (Casanova Formation (Fig. 6, 12, *a*). These ophiolite incorporations are mostly represented by mantle and basalt flow sequences. Gabbros and basalts from the EL ophiolites show a MOR-type geochemical signature [Tribuzio et al., 2004; Montanini et al., 2008], whereas associated mantle bodies retain a subcontinentalAdria-derived lithospheric signature [Rampone et al., 1995]. Successions of the EL domain are characterized by thick Upper Cretaceous carbonate flysch deposits (Helminthoid Flysch) (Fig. 12, *b*), which overly associated sedimentary mélanges with ophiolite incorporations (Casanova Formation) (see Fig. 6, 12, *a*).

Conclusions. The study region is characterized by a complex tectonic evolution derived from complex interference, in space and time, of two diachronous oppositely dipping subductions: a Late Cretaceous — Middle Eocene east-dipping «Alpine» subduction and a Late Eocene — present west-dipping «Apennine» subduction. This results in a fold-and-thrust belt of Northern Apennines of E- to NE-verging structural units with the Ligurian Units at the top of the tectonic pile, thrust over the underlain units (Subligurian and Tuscan Units).

The paper considers the northern sector of the Apennines formed by closing the narrow Piedmont-Ligurian Basin. The opening of the latter in Jurassic time between the Adria plate (northern African promontory) and Iberia (proto-Europe) was caused by the opening of the Central Atlantic on the transform fault. Because of successive tectonic events in the Piedmont-Ligurian Basin, such as opening, rifting, drifting, and the following accretion-subduction processes, lithospheric remnants of the Piedmont-Ligurian Basin were brought to the sea floor and then to the surface. The ophiolite bodies of the Alpine-Apennine belt now expose in the Ligurian Units.

The authors studied these rocks of the oceanic lithosphere, exposed in the Northern Apennines and Southern Alps, during several geological excursions. These rocks of the ophiolite complex were formed at magma-poor ocean-continent transition; some bear similarities to the oceanic lithosphere from slow and ultra-slow spreading ridges.

On the example of Bracco-Levanto ophiolite body, we studied the whole cross-section of the ophiolite complex overlain by Cretaceous-Paleogene sedimentary successions (limestones and sandstones). The ophiolite complex starts from peridotites, lherzolites, serpentinites, and ophicalcites of total thickness up to 500 m, with intrusions of gabbro and intercalated breccia (gabbrobreccia) of the same thickness. Up the section, basalts (massive ones as thick as 550 m and a thin layer of pillow basalts) and radiolarites replace them.

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Офіолітовий комплекс П'ємонт-Лігурійського басейну (Північні Апенніни)

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Північні Апенніни містять залишки П'ємонт-Лігурійського басейну (ПЛБ) або океану, який протягом пізнього мезозою (головно у юрському періоді) відокремлював Палеоєвропу (Іберійську плиту) від південного палеоконтиненту Адрія на Африканському виступі. Закриття ПЛБ і подальша колізія Європа/Адрія у крейдяно-кайнозойський час привели до ексгумації офіолітового комплексу Північних Апеннін, що відбулася в лігурійських підрозділах. Наведено інформацію, отриману авторами під час кількох польових екскурсій, про склад офіолітового комплексу Північних Апеннін, що є репрезентативним для складу та структури океанічної літосфери. Склад офіолітового комплексу, відсутнього на території України, є ключовим питанням для розуміння еволюції океанічної кори, процесів субдукції та формування акреційних призм у перехідних до континентів зонах. Лігурійські офіоліти ПЛБ являють собою доступне та унікальне вікно для відстеження відкриття та еволюції океанічної літосфери з повільним спредингом. Внутрішні Лігурійські офіоліти складаються з тіл габро у деплетованих мантійних перидотитах і характеризуються надзвичайною структурною та композиційною подібністю до океанічної літосфери хребтів з повільним та надповільним спредингом. Зовнішні Лігурійські офіоліти, пов'язані з матеріалом континентальної кори та перехідною зоною між океанічною та континентальною корою, включають мантійні послідовності субконтинентального літосферного походження. Габро-перидотитові асоціації Внутрішніх Лігурійських офіолітів досліджено в офіолітовому масиві Бракко-Леванто, який вміщує тіло габро розміром декілька кілометрів, що нагадує комплекси океанічного ядра із сучасних центрів спредингу в мантійних перидотитах. Перидотити та габро з цих офіолітів відображають складну історію, що включає деформацію та зміну умов від високої температури до температурі морського дна. Поверхня перидотитів вкрита тектоно-гідротермальними брекчіями (офікальцитами), радіоляритами та осадовими брекчіями, що засвідчує відслонення перидотитів на морському дні. Ця послідовність потім вкривається базальтовими подушкоподібними лавами, тобто представлений майже повний розріз офіолітового комплексу.

Ключові слова: Північні Апенніни, П'ємонт-Лігурійський басейн, Лігуриди, офіоліти, перидотити, акреційний клин (призма).