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United Nations Framework for Resources Case Study: Titanium deposit, the Piampaludo exploration project in Italy

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Summary

This case study demonstrates the application of the United Nations Framework Classification for Resources (UNFC) to a titanium exploration project (Piampaludo) in Liguria, Italy. It is an attempt to introduce UNFC to Italy. The Piampaludo exploration project is reported to be one of the largest deposits of titanium in Europe with the potential for significant economic importance, yet its development is constrained by environmental and social considerations. UNFC is a classification tool that provides end users with an assessment of a resource project to allow informed decision making as part of sustainable resource management. The case study demonstrates the classification process for the Piampaludo exploration project, highlighting the social and environmental constraints according to the transparency needed for UNFC, using only data available to the public. Therefore, the information presented in this case study results in a classification sufficient for local and national mineral inventories. For that purpose, this report emerges as an educational example of the use of UNFC with only publicly available data and not on accessing detailed exploration information that would be available to Compagnia Europea per il Titanio, the current owners of the Piampaludo exploration project.

In light of the limited data availability, it is important to note that this case study is not a resource analysis that provides comprehensive and complete insights. The data collected for the classification was limited and restricted, and therefore, the analysis presented is not exhaustive. This case study is a "light" study without the detailed data of sufficient quality and quantity required for the “true classification of the project”. With these caveats and limitations, the study presents a correct classification based on the available data and presents the resultant downgrading of the estimate confidence in comparison to a “true classification”. If additional information does become available, the conclusions drawn from this study will need to be revised but even with the limited information, the exercise provides valuable insights into the resources for decision-making purposes.

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Contents

I. Introduction

1. The world understands the necessity to make progress towards attaining the 2030 Agenda for Sustainable Development. Evidence for this need stems from global trends that indicate a shift towards difficult living conditions if no actions are taken with regard to economic growth, social wellbeing, and environmental protection. In addition, it is understood that it is desirable to leave a prosperous planet with better living standards for our future generations. Achieving this goal is dependent on the responsible use of minerals and energy and the participation of extractive industries, in particular the mining industry. Minerals are integral for the sustainable development and industrial progress. In contrast, mining and its inherent activities are often viewed as inconsistent with the goals of sustainable development. Therefore, the mineral extraction needs to embody a sustainable management approach in all mining activities, from exploration and extraction to processing and recycling, that is built on a classification system that expresses the environmental-socio-economic systems, technical aspects, and the level of knowledge in the product estimates; the United Nations Framework Classification for Resources (UNFC).

2. UNFC is a global, robust, and exhaustive classification system with a structured framework of principles, rules, and guidelines. UNFC is developed for a wide range of resource and energy projects including minerals, petroleum, renewables, underground storage, and anthropogenic resources. This tool provides information on project maturity pertaining to policy formulation, resource management functions, business process, and capital allocation [1]. UNFC is established on three fundamental pillars for every resource and energy projects: the environmental, social, and economic viability (E axis), the technical feasibility (F axis), and the degree of confidence in the estimate of resource quantity (G axis). The integration of these axes makes UNFC a useful communication tool to express complex concepts to stakeholders in a clear and unambiguous fashion.

3. According to the European Union (EU)-funded project Mineral Intelligence for Europe (Mintell4EU), Italy has a significant number of mineral occurrences and deposits, which include several containing Critical Raw Materials (CRMs) (Figure I) [2]. The Geologic Survey of Italy (ISPRA) has identified more than 3,000 mining sites that have been constructed on Italian territory since 1870 [3]. However, Italy has neither a formal national nor regional classification or reporting policy for primary and secondary mineral resources to direct the mining industry. The lack of a national, regional mineral reporting system in Italy has contributed to the reduction of mining activities in the country over the last decade. There is no comprehensive and sustainable information for interested stakeholders on mineral potential for new prospection of mineral resources or even reactivation of historic mines.

4. With the addition of the current challenge of enhancing the security of CRMs supply in the EU and the support of energy transition, there is a need in Italy to map its potential mineral resources. Securing mineral resources starts with the correct mapping of supply and demand with sustainable considerations. Minerals require coherent definition and classification at national, regional, and global scales. This can be achieved through the application of UNFC, as is underlined as an action module in the EU financed project: Piano Nazione di Represa e Resilienza (PNRR) [4].

5. This report presents a case study on the application of UNFC to a titanium exploration project (Piampaludo) in Liguria, Italy. This case study is an attempt to apply UNFC to a unique deposit in Italy and determine the projects status using the classification tool. The challenge of the Piampaludo exploration project is that it is one of the most significant deposits of Titanium in Europe with potential economic importance, and yet it is constrained by environmental and social considerations. The classification of this project was inspired by the UNFC Guidance Europe document for minerals and anthropogenic resources in Europe [5]. This report highlights the classification of an exploration project according to UNFC using only data available to the public. Information from the company in charge of the project, Compagnia Europea per il Titanio (CET), were not disclosed due to the social sensitivity of the matter, and company confidentiality. Therefore, all information used for the classification of the Piampaludo titanium exploration project are strictly from public data: from scientific research studies, journals, news, and court cases. It should be noted that higher confidence in a UNFC classification requires more detailed exploration activities provided

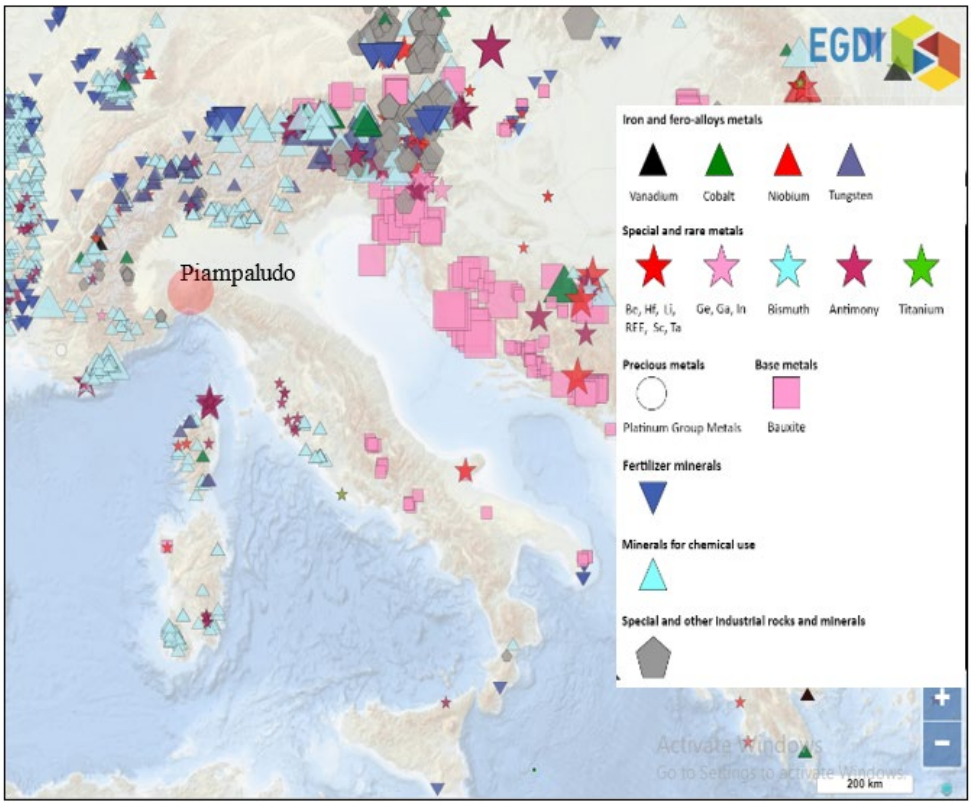
by the CET, which is inaccessible for this case study. However, the information used in this case study results in a classification sufficient for the mineral inventory of the Liguria region. For that purpose, this report is an educational example of the use of UNFC with only publicly available data, and not on accessing detailed exploration information that would be available to CET. The assessment of the Piampaludo project using the available social and environmental information is further elaborated in this document. End users can take this classification and request additional information according to their needs.

6. The classification of the Piampaludo Titanium exploration project using UNFC can also be used to demonstrate the evolution of a project's viability over time. Mining should be planned with respect to land and environmental policy and regulatory frameworks. Therefore, the changes in the classification observed in this report emphasize the changing environmental-socio-economic aspects of each decision through time and their resultant impacts on the UNFC classification.

7. The Piampaludo exploration project is located in the Beigua natural regional park, which is Italy's largest protected park. The Beigua Park is intended to conserve the geologic history by safeguarding the natural heritage showcased in the park. The goals of protecting the environmental resources by managing social and economic development are based on the Italian law on protected areas (L. 394/91). The Beigua Park has also been incorporated into Europe's Natura 2000 network, due to the presence of exceptional and rare bird species [6]. The social and environmental impacts linked with the Beigua Park and the Natura 2000 network are major impediments facing the Piampaludo project. These impediments and their implications are explained later in this document.

8. The Piampaludo exploration project is a rich metamorphic-type titanium deposit, which are very attractive to the EU market as indicated by its inclusion in the list as a CRM in 2020 [7]. The titanium of Piampaludo is found as high-grade concentrations of rutile, a titanium dioxide mineral (TiO_2), hosted in large tonnages of the metamorphic ore rock eclogite. The ore grade and tonnage have been corroborated by several series of testing throughout the years, at laboratory scale and in the field. Most of the studies and tests on the Piampaludo ore were carried out by the "*Società Mineraria Italiana*" (Italian Mining Company) and "*Mineraria e Metallurgica di Pertusola*", on eclogite samples extracted from up to a maximum depth of 115 meters by boreholes. Drill hole sampling and in situ samples collection led to an analytical understanding of the mineralogical, petrographical, and chemical characteristics of the ore [17]. Preliminary development of the Piampaludo site was conducted by the previous mine owners "*Mineraria Italiana Srl*" in 1975, and by the current owners CET. The developments included surface trenching, adits, and a shaft. Additionally, academic researchers have carried out geophysical and geochemical studies, and geologic mapping based on core and surface sampling [12]. The technical and geologic information used for this classification are therefore, based on these tests.

Figure I
Critical Raw Materials occurrences in Italy [2]



Note: Based on the European Geological Data Infrastructure (EGDI) database that aims at mapping all mineral deposits in EU. The Titanium occurrence of this case study do not appear on the map, which exemplifies the lack of mineral reporting in Italy.

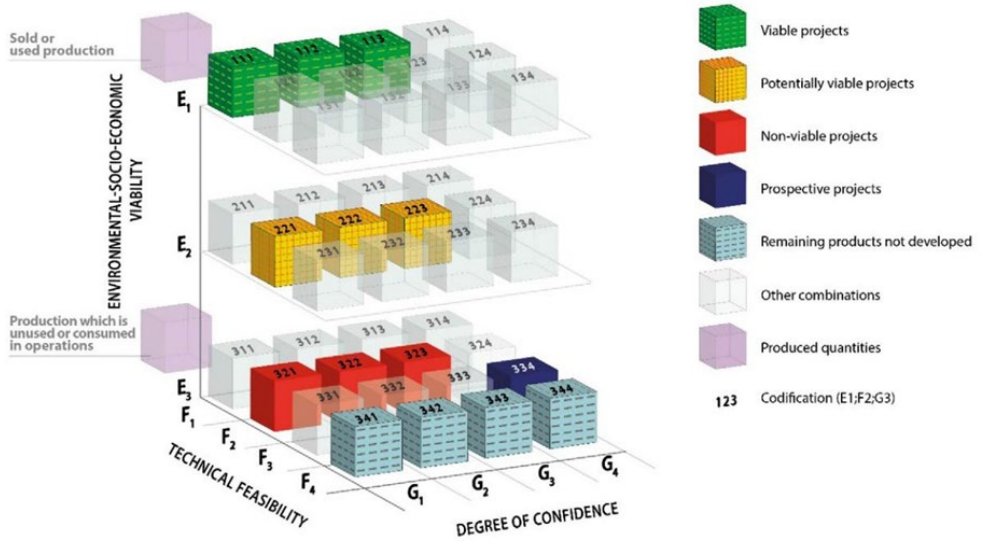
II. The United Nations Framework Classification for Resources

9. UNFC is a global, robust, and project-based classification system built on a structured framework of principles, rules, and guidelines. It is designed to provide the necessary project information relating to policy formulation, resource management functions, corporate business process, and financial capital allocation.

10. The classification of a project in UNFC is based on three fundamental criteria: the environmental-socio-economic viability (E axis), the technical feasibility (F axis), and degree of confidence in the estimate of resource quantity (G axis). These criteria are illustrated in the diagram on the axes (Figure II). Each criterion is assessed and classified individually, until assigned a class. In return, each class for each criterion is subdivided into subclasses, according to the project's maturity. The combination of the three axes creates the Categories and Sub-Categories, which are the building blocks of the classification system.

11. Each Class has a unique description defined by the selection of the relevant combination of the three criteria of a particular Category or Sub-Category. Although the various combinations of E, F, and G Categories and/or Sub-Categories have no explicit constraints, some are more remarkable than the others.

Figure II
UNFC Classification System



12. In this case study, the UNFC concept and specifications for its application adopted pertain to mineral resources. The relevant terms, principles, and definitions are found in the UNFC Minerals Specifications document [8].

13. The classification of Piampaludo using UNFC begins with an investigation of all publicly available information on the deposit including previous studies and tests done in the region on field and in laboratories to understand the geology. Ideally the best information for the classification would be based on the estimates of a qualified person regarding ore grades, quantities (tonnage), and continuity/distribution, with the appropriate quality control and quality assurance methods. These estimates would be supplemented with field sampling and surveying, surface and subsurface, carried by the current project owners, as well as independent researchers. Unfortunately, this information is not available from CET due to the sensitive nature of the site and its resources. This information would provide for better accuracy in the estimates of Piampaludo's titanium ore quantities, the G axis. Instead the document must rely on compilations and reports in the academic literature to provide the information needed for the G axis. In contrast the environmental-socio-economic maturity can be accurately assessed on the basis of the project's current status in terms of permits granted and court decisions. Piampaludo's technical feasibility is evaluated according to the previous developments held on site during earlier exploration.

III. The Piampaludo Exploration Project

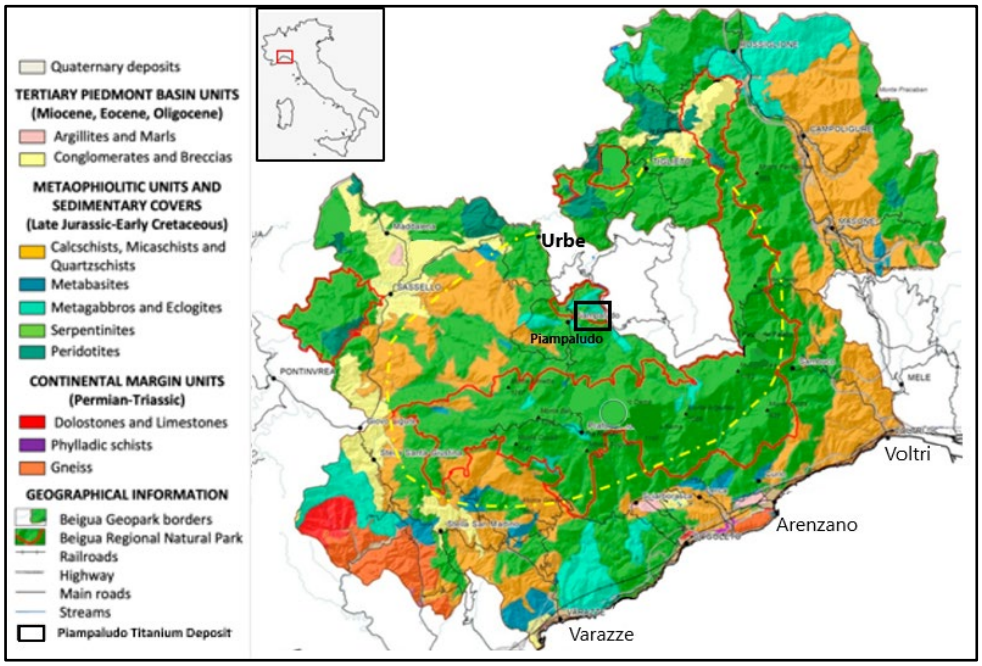
Figure III
Location of the Piampaludo titanium deposit

Note: The image on the left shows the extension of the Piampaludo titanium with respect to the Natural Park, and the image on the right shows the deposit with respect to Monte Tariné and Monte Antenna.

14. The Piampaludo titanium deposit is located in north-east Italy, in between the Urbe and Sassello provinces, in Liguria. The titanium deposit is found between the mountains of Monte Tariné (930m) and Monte Antenna (670m) at approximately 850 metres above sea level [9].

A. Geology of Piampaludo

Figure IV
Geological map of Piampaludo [9] with the park limits outlined in red



15. The extension of Monte Tariné, where the deposit is found, belongs to the Voltri Massif within its south-eastern marginal unit in the Ligurian Alps, referred to as the Voltri-Rossiglione Unit. To be more specific, the Voltri massif is found on the Piedmont-Liguria border (Figure V).

16. The Voltri Massif is a large ophiolitic massif located in the Alpine-Apennine chain, the western Alps. The units of the Voltri Massif underwent metamorphism during the Alpine convergence [22].

17. It is represented by a polyphase deformed and metamorphosed ophiolotic formations with metasedimentary interlayers and slivers of sub-continental lithospheric mantle. The Voltri Massif is subdivided into five distinct units, often referred to as Voltri Group: four of them are composed of meta-ophiolites corresponding to serpentinite, metabasites, metagabbro, calcshist, and minor mica and quartz-schist, and an overlying unit of mantle rocks consisting of lherzolite and harzburgite peridotites, associated with minor dunites and pyroxenites (Table 1) [10]. The Voltri group displays features from the subduction of the Piedmont-Ligurian oceanic lithosphere, in the Alps-Apennine portion of the Tethys, during the Mesozoic era [11]. The oceanic basin underwent intra-oceanic subduction, followed by collision during the early Cretaceous with the European continental crust, which led to emplacement of the Voltri group along the Alpine zone [12].

Figure V
Regional geology: Ligurian – Piemontese geologic units [10]

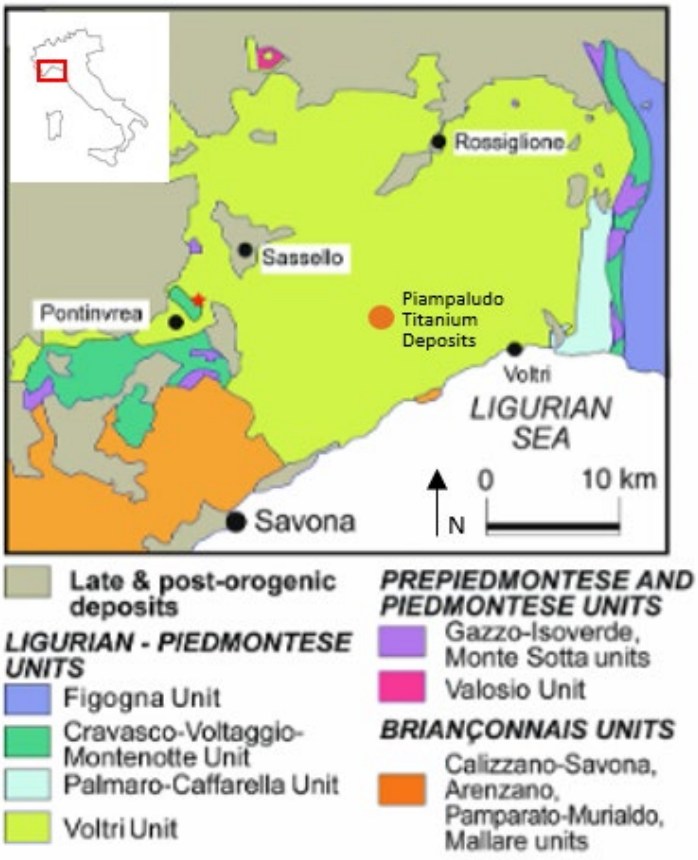


Table 1
Stratigraphy of the Voltri Group

Formation	*Location*	*Geology*	*Structure*
Monte Tobbio Peridotites	Northeastern part of Voltri group	Serpentinized peridotite + lherzolite + harzburgitic bodies + dunite lenses + bands of pyroxenite	Remnant mantle texture, mainly tectonic foliations
Bric del Dente Serpentinites	Dominant lithology of the Voltri group	Serpentinite + serpentine-schist + antigorite, magnetite + chlorite + olivine + diopside + tremolite + ankerite + Ti-clinohumite	Relic texture of the original peridotite. Multiple folds with shear bands
Colma Metagabbros	Southern part of the Voltri group	Leucocratic metagabbro + garnet + Cr-mica + omphacite + glaucophane + albite + tremolite + Mg-chlorite + epidote + traces of white mica + titanite + talc + oxydes	Relic eclogitic paragenesis
Voltri-Rossiglione Metabasites	Southeastern part of the Voltri group	Ca-amphibole + chlorite + albite + epidote + minor Fe-Ti oxides + titanite + talc + biotite + calcite + white mica. Local Na-amphibole + rutile + garnet	Layered or foliated textures of melanocratic and leucocratic facies. Original textures erased by metamorphism and deformation
Turchino Calcschists	Western part of the Voltri group	Micaschist + quartz-micaschist + carbonate schist with quartz + white mica + calcite + chlorite + biotite + pyrite. Local garnet + chloritoid + mica	Re-equilibrated green-schist facies conditions. Different deformational events across all outcrops

18. The stratigraphy containing the titanium deposit of Piampaludo, is part of the Voltri-Rossiglione unit of the Voltri massif. The Voltri-Rossiglione unit was metamorphosed at peak conditions of pressure ranging from 18 to 22 kbar and temperature between about 500-600℃, typical of the eclogite facies. Garnet, omphacite, rutile, Na-amphibole, phengite, clinozoisite were formed in Fe-rich metagabbro during this metamorphism.

19. The titanium ore consists of the rutile concentrated in eclogitic rock masses. The eclogites of Piampaludo are primarily composed of garnet, Ca-, Na-, Fe-, and Al-silicates, rutile, as well as concentrations of pyroxene and glaucophane [13]. The eclogites of the area are erosion resistant with very hard and compact properties [14].

20. According to the mineralogical and chemical analyses of Piampaludo eclogite samples, collected from boreholes at a depth of 41.5 meters, the rutile is in masses several millimetres across, and locally in aggregates in the order of centimeters. Electron microprobe analysis and X-ray diffractometer tests performed on samples demonstrate the titanium content of the aggregates (Tables 2 and 3) [17]. Individual rutile crystals range from 30-40 μm within these aggregates, with a clear metallic luster and vary in color from brown to yellow. Rutile is restricted to the aggregate concentrations, but can form an average of 65% of the aggregates. In some cases, the rutile dimensions tend to be 0.5-3 mm across and display an orientation parallel to the foliation [16].

21. The titanium dioxide concentrations within the eclogites are denoted to have a grade of about 6% TiO_2, with localized enrichments up to twice that. It is also indicated that the total rutile weight in the rock mass is 9 Mt [14][15]. Additional, reports based on field tests and research projects indicate that the rutile concentrations extend over 400 Mt at depths below 500 meters [15]. The orebody is characterized as massive, but highly fractured, with a low schistosity. Geophysical data determined that the orebody dips 20˚South, as a largely concordant lens [16]. The characteristics of the orebody were determined by preliminary developments carried out by "*Mineraria Italiana Srl*" and "*Compagnia Europea per il Titanio"*, who were both once granted mining concession post 1976. CET managed to carry out surface trenching, adits, and a shaft based on studies from drill holes, geophysics, geochemistry, and geological mapping and presumably have a much greater understanding of the deposit. However, for this case study, the characteristics reported in publicly accessible information are summarized in Table 3.

22. About 30 to 40% of the deposit consists of garnet concentrations (Figure VI) [17]. Results of the X-ray diffractometer analysis performed on the Piampaludo eclogitic ore indicate that the available garnet is frequently iron-rich (more than 66%) and manganese-poor (less than 15%) [17]. Garnet, as a by-product of the rutile, can be used to improve the economic viability of the Piampaludo project, since Fe-garnet, known as Almandine, is considered to be an attractive gemstone in the jewelry industry, or a good abrasive for sandpaper.

Figure VI
Microscopic view of the Piampaludo eclogites (ca. x20) [17]

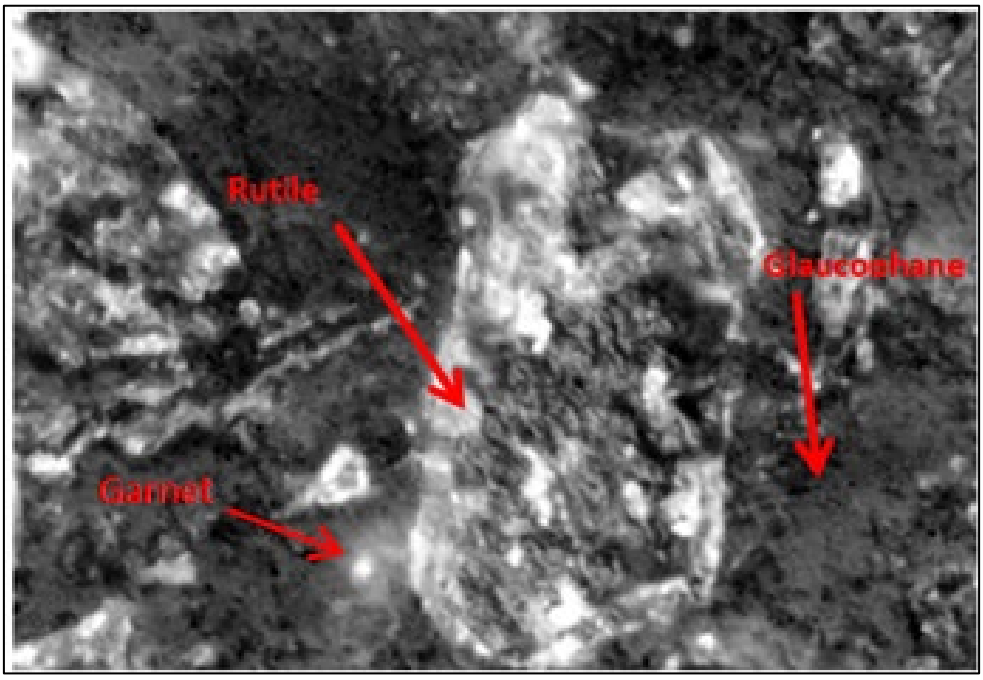


Table 2
Chemical analysis of eclogites from Piampaludo [17]

% Oxides	1	2	3	4	5	6	x	ב
SiO_2	54.48	51.75	52.82	53.89	51.96	53.25	53.03	1.07
TiO_2	0.92	0.88	0.12	0.68	0.76	0.44	0.63	0.30
Al_2O_3	8.51	4.79	11.37	10.64	10.23	11.25	9.46	2.51
FeO	9.19	15.77	10.66	9.47	11.66	10.11	11.14	2.43
MnO	0.04	-	-	0.28	0.21	0.12	0.16	0.10
MgO	6.58	6.60	6.29	5.78	5.34	6.10	6.11	0.49
CaO	10.64	13.12	7.63	8.34	8.62	9.41	9.63	2.00
Na_2O	9.74	5.91	9.98	10.27	11.31	9.18	9.40	1.85
K_2O	0.08	0.07	0.16	0.09	0.09	0.12	0.10	0.03
Total	**100.18**	**98.89**	**99.03**	**99.44**	**100.18**	**99.98**	**99.62**	**0.58**

Table 3
Chemical analysis of rutile in eclogites from Piampaludo [17]

% Oxides	1	2	3	4	5	6	x	ב
SiO_2	0.10	0.18	0.19	0.13	0.18	0.21	0.16	0.04
TiO_2	98.35	98.05	98.51	98.19	98.34	97.80	98.21	0.25
Al_2O_3	0.13	0.11	0.17	0.37	0.10	0.18	0.18	0.10
FeO	0.41	0.22	0.32	0.48	0.41	0.26	0.35	0.10
V_2O_3	-	-	-	0.54	-	0.06	0.07	0.03
MgO	0.05	0.10	0.11	0.04	-	0.06	0.07	0.03
CaO	0..06	0.12	0.08	-	0.11	0.07	0.09	0.03
Na_2O	0.12	0.23	0.17	0.17	-	0.13	0.16	0.04
Total	**99.22**	**99.01**	**99.55**	**99.92**	**99.77**	**99.13**	**99.47**	**0.37**

Table 4
Piampaludo titanium orebody characteristics

Location	Piampaludo, Liguria, Italy
Regional Geology	Voltri Massif
Formation	Voltri-Rossiglione Metabasties
Age	Jurassic to Cretaceous
Overburden	Oligocene clastic sediments
Geologic Setting	Ophiolites and metasediments
Rock type	Eclogites
Physical Features	Massive, very compact, hard rocks
Ore mineral	Rutile (TiO2)
Ore occurrence	Aggregates ~ 0.5-3mm
Ore tonnage	9Mt
Ore grade	~ 6%
Orebody morphology	Large concordant lens
Orebody orientation	20˚Dip to the South
Associated minerals	Garnet, Glaucophane, Titanite, Ilmenite, Serpentine, Talc, Magnetite, Actinolite

B. CET Mining Plan

23. The majority of the exploration and geo-technical development of the property was completed by CET. CET earned the mining concession for the Piampaludo project in 1985. The permit had been transferred to CET from "*Mineraria Italiana Srl*", who earned the initial concession to mine the Piampaludo Titanium in 1976, from the Ministry of Industry of Italy. CET is a very small company with a share capital of only 10,400 euros, without historic mining experience and know-how in the sector, represented and hosted by an accounting firm in Cuneo, Italy.

24. CET conducted preliminary feasibility studies during the permitted period, leading to the development of a comprehensive mining plan. The prefeasibility study was supported by surface preliminary developments, such as adits, trenches, and a shaft. Additionally, CET, completed drilling with coring and collected samples from a maximum depth of 115m, performed during a sampling survey carried out by "*Società Mineraria Italiana*", supported the technical and geologic investigations for the development of a preliminary mining plan. However, it is necessary to note that no information regarding the drilling spacing and density was disclosed by CET [17].

25. The geology of Piampaludo was mapped during the investigation phase. Both geophysical and chemical analyses were applied concurrent with CET's preliminary development, which served to accumulate a considerable dataset of information. An initial mineralogical examination of the eclogitic ore revealed notable assemblages of rutile associated with minor Mg-Fe garnets, and other minerals. The rutile was found to be as pure as 99 wt % TiO_2. The initial developments conducted by CET included the construction of a pilot shaft [16].

26. A comprehensive mining plan was developed by CET for the recovery of rutile, with garnet as a secondary product. The plan included detailed information on production, mine lifecycle, transportation, market, and waste management (Table 2). According to CET's mining plan available online, the mining activity would be in open pit with a lifespan of 90 years and a production rate of 10,000 t/d of ore, equating to 163, 240 t/y of rutile produced, down to a depth of up to 500 m [16]. Mining wastes composed largely of garnet were foreseen to be conveyed 3 km by gravity flow tunnels towards the coast of Liguria, at a maximum flowrate of 9,400 t/d [16].

Table 5
CET mining plan proposal for the Piampaludo project

CET Proposed Mining Plan as part of the Piampaludo Prospect Project	
Type of Mining	Surface
Mining Method	Open Pit
Mining Technique	Drill & Blast
Surface Area	90 Hectares
Maximum Pit Slope	60 °
Operating Days per Year	265
Operating Shifts per Day	2 shifts of 8 hours each
Production	10,000 t/d
Production Unit Cost	1.37 $/t ore[a]
Waste Rock	48.4 %
Ore Mining Features	
Ore Hardness	Hard Rocks (Eclogites)
Length	~ 1,800 m
Width	500 m
Thickness	300 m
Wall-Rock Alteration	None
Ore Control	Fracturing
Latest Ore Record	1991

[a] Subject to conversion into today's market price.

C. Social and environmental contingencies facing Piampaludo

27. While the Piampaludo project appears to be economic, it has not been exploited since its discovery. Currently, the titanium ore is located in a Natural Preserve region, which has caused the project to be hindered by social and environmental challenges.

28. All mining operations relating to the Piampaludo project, including exploration, ceased when titanium occurrence was included in the Beigua Natural Park, in 1995.

29. The Beigua Natural Park is the largest protected park in Italy [18]. Various features in the park have warranted the protected status, and has an outstanding geologic heritage, from outcrop features to the preserved fossils. The Beigua GeoPark is mandated to conserve the geology and to safeguard the natural heritage. The mission aims to protect environmental resources by managing social and economic development, according to the Italian law on protected areas "*Legge quadro sulle aree protette*" (L. 394/91).

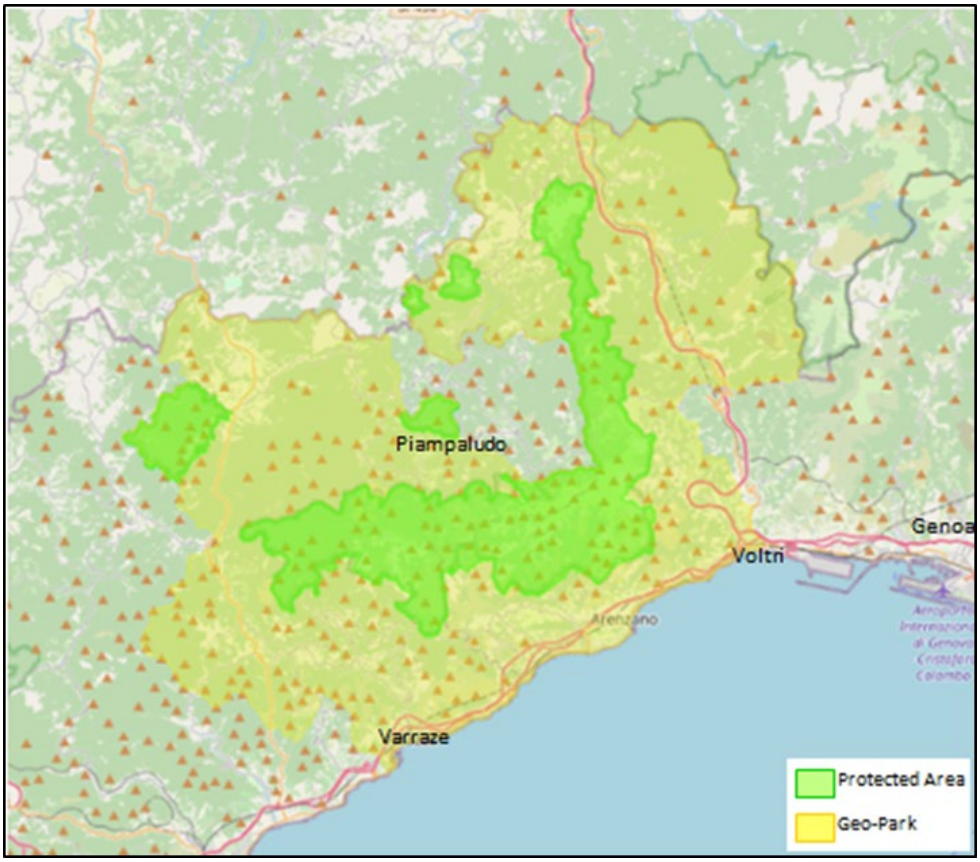
30. The Beigua Geopark has been included in the Europe's Natura 2000 network, to protect rare bird species hosted in the park [18]. The Beigua Natural Park includes a wide range of fauna and flora, with 26 different types of ecosystems. There are considerable wetlands at the park that exhibit significant environmental settings for many organisms of natural value. Both, geo- and bio- diversity observed at the Beigua Natural Park are focal points for social and environmental concerns to preserve these natural settings. These are supported by the touristic and historic values of the Park, with geotourism museums and Roman archaeological artefacts.

31. Politically, the Ligurian region supports the social and environmental protection of the area, with additional support from neighbouring municipalities and environmental activists. These groups are opposed to any mining operations within the borders of the Beigua Park the Natura 2000 borders of the region (Figure VII).

32. As a consequence, the efforts to protect the area have forced operations in Piampaludo to cease. Several legal actions have been initiated by stakeholders opposing mining companies interested in this deposit [19].

33. According to the European Commission (EC), mineral exploration is permissible in Natura 2000 sites, under the condition that the resiliency of ecosystems and the integrity of the entire site are not severely disturbed. The conditions required to build a mine could be met by comprehensive short- and long- term strategic planning for the operation, requiring the inclusion and consent of stakeholders to avoid future issues. This would allow the operation to remain consistent with sustainable development principles and policies [20].

Figure VII
The Beigua Geo-Park [21]



IV. UNFC Classification of the Piampaludo Project

A. G3+G4 classification on the G Axis, the Degree of Confidence

34. The titanium ore in Piampaludo has been a subject of interest for many researchers, scholars, and mining companies for years. CET considers that sufficient studies and tests have been completed to support the regional geology, as well as the titanium volume and recovery, supported by the thorough analyses done over the years [12] [17]. In addition to the tests conducted for scientific purposes, the site was a subject of prospecting tests to supplement the detailed exploration evaluations. However, no information on the testing results and reporting have been publicly disclosed. It is important to note that these estimates are on studies conducted between 1979 and 1998, leaving most of the scientific geological information inaccessible to the public, yet the technical data on the Piampaludo titanium ore are not.

35. According to UNFC-2019, product quantities of prospecting projects are classified as G4. The Piampaludo titanium ore quantities from the publicly available data are assessed with confident estimates from laboratory analyses and field observations and developments, which allowed the estimations to be at moderate to low levels of confidence. Another factor that supports this statement is the continuous pursuit for mining by CET, over the years. With that said, the titanium ore has moderate probability to equate the estimated quantities.

36. According to the results of the X-ray diffractometer analysis performed on the Piampaludo eclogites, garnet is strongly present, mainly as iron-rich garnet [17]. In addition, various sources available online state that garnet could be a viable by-product of the rutile extraction [19]. However, given the inferred quantities, the garnets are presumed to present less economic importance compared to those of the titanium. The garnet quantities are estimated with less certainty because of the fewer available information, rendering the confidence in the estimates to low degrees. It is necessary to mention, for the accuracy and

reliability of the assessment, that these estimates are based on data lastly updated in 1991, which makes them historic results and should be valued with lower certainty today.

37. Thus, for the purpose of assessment quality, a conservative approach was followed to classify the Piampaludo project as G3+G4 on the degree of confidence, the G axis.

B. E3.2 classification on the E Axis, the Environmental-Socio-Economic Viability

38. The Piampaludo Project currently has exploration permit, which was granted to CET by the Regional Council of Liguria in 2021. Table 6 demonstrates the paucity of information available to classify this project and the main social and environmental impediments tied to it. Table 7 presents the chronological events related to the Piampaludo exploration project from discovery to now.

39. The Piampaludo Project began with a 20-year mining concession and was approved for Mineraria Italiana Srl to recover titanium in 1976. The concession was transferred to the current owners CET in 1985. Since 1991, CET has been requesting for an extension of 20 years for the mining license from the Ministry of Industry in Italy, yet the social and environmental concerns have delayed the procedure. The Piampaludo area was protected by various regulations. Concurrently the Ligurian Regional Law "n.12/95" structured and supported protective functions over the land included in the Beigua Park, and an area that included approximately 50% of the Piampaludo ore field. For over 35 years, the land has been an environmentally protected area for its nature and ecosystem and exploration has been prevented [17].

40. Legal disputes continued in the fall of 2014 when CET applied for a new exploration permit for the Piampaludo titanium, garnet and associated minerals. In 2021, the project was approved for exploration rights on the half of the resource area (around 229 ha in surface area) which is not included within the Beigua Park domain, under act n. 1211 of 02/26/2021. CET maintains complete exclusivity for exploration in this area. Additionally, this permit allows CET to develop preliminary studies and tests on the designated half, with the intention of evaluating the areal and surface distribution, and to confirm and re-evaluate the rutile concentrations.

41. An exploration permit was granted until 31/12/2023 [19]. CET's planned investigation and studies do not intend to alter the natural state of the field, as was highlighted in the court appeal. The exploration strategy is to use approaches with minimal negative environmental impacts and landscape disturbance; Sampling shall be carried out on foot, as well as the geological and structural surveys and mapping, using the existing trails [19]. CET is likely to undertake EIA and SEA to identify and mitigate environmental concerns, and to solidify their case for future recovery.

42. From the economic side, Piampaludo's titanium deposit certainly exhibits great economical potential, given the measured ore-grade and tonnage. The Piampaludo Project has been estimated to generate approximately 500 M€ in royalties for the region of Liguria, with the deposit valued between 400 and 600 B€. In 2021, the price of rutile per ton was worth a bit over 2000 euros [18]. With this price, and the given rutile grades at Piampaludo, the deposit is estimated to be valued at minimum 120 B€ [18]. Although titanium deposits with these grades and tonnages could be cost-effective, conventional mining is not expected to be accepted from the environmental and societal point of view, therefore other methods need to be considered with the appropriate environmental measures, which makes the operations more costly.

43. At present, the development of the project is not assured to be environmentally-socially-economically viable based on the limited available information. Given both the continuous opposition facing the project and the recent permit given to CET, it is too early to determine the environmental-socio-economic viability of the project. Accordingly, in order to be more conservative with the classification and respecting the lowest rank prevails rule, the project is classified as E3.2 on the E axis.

Table 6
Piampaludo project social and environmental impediments

Environmental factors	
Project located in a restricted area	- Natural protected area - Beigua Natural Geo-park and Natura2000
Flora and fauna to be protected	26 different ecosystems -Fauna • Buzzard (*Buteo buteo*) • Biancone (*French Circaetus*) • Falco pecchiaiolo (*Pernis apivorus*) • Ferro di cavallo maggiore (*Rhinolophus ferrumequinum*) • Bechstein's bat (*Myotis bechsteinii*) -Flora • Elleborine palustre (*Epipactis palustris*)
Available critical ecological land-use planning	Maybe, but not publicly disclosed
Critical land use	Not available
Social variables	
Presence of indigenous communities	No
Within indigenous region	No
Social land ownership	Not available
Presence of marginalization as per the marginalization index	No
Project interference with an economic activity	Tourism at the park
Water concern	Not available
Legal variables	
Legal status of the project	CET currently holds exploration grant on 229 hectares of land
Available environmental approvals and permits	No EIA nor any environmental permits are yet presented
Social assessments presented - Social Impact Assessment?	Social Impact Assessment not carried out, yet local and neighbouring communities are strongly against the project

Table 7
Permitting timeline of the Piampaludo project with respect to the E axis

Period	*Event*	*E axis Category*
1976	Mineraria Italiana Srl granted mining concession	E1.3
1985	Mining concession transferred to CET	E1.3
1991	CET request 20 years concession renewal from the Ministry of Industry, no answer to date	E2
1995	Area included in the Beigua Park any mining or related activity was interrupted	E3.3
2014	Court objects to CET's request to obtain new mining research permit	E3.3
2015	Court objects to CET's appeal for the annulment of the inadmissibility of the application relating to the mining research activity	E3.3
2015	Court rejects CET's request to activate the procedure for the EIA for geological surveys	E3.3
2020	Court rejects CET's plea to challenge court's decision, entrusting the recourse to Violation and/or False Application of Law	E3.3
2021	Regional Council of Liguria confers in favor of CET, granting the research permit on the mainland of solid minerals (Titanium, garnet and associated minerals) for 3 years	E3.2

C. F2.2 Classification on the F Aaxis, the Technical Feasibility

44. The technical feasibility for the Piampaludo project can be deduced from the preliminary plan proposed by CET (Table 2), with the support of tests done for research purposes [14][17][18]. These studies represent a starting point that can be used by CET, given their newly acquired exploration right. Granted that the Piampaludo project is still an exploration project, the prefeasibility planning indicates potential development, yet it provides insufficient information on the probability for progression in developments while upholding a clear resource definition, therefore, further data acquisition is needed to evaluate the feasibility of development.

45. At present, activities for the advancement in technical development at Piampaludo are still pending due to the ongoing environmental and social impediments tied to the project. This reluctance to initiate activities may result in significant delays for development. The technical feasibility for this project is yet at preliminary stages, despite the promising indications. More detailed data are needed to confirm the feasibility of future developments.

46. To this point, CET's preliminary developments include a shaft and adits. According to CET these developments have provided sufficient data on the titanium ore to confirm that it should be considered a promising prospect. Given the prospective economic benefits of the ore, one can comprehend the stakeholder's willingness to increase investment to ensure that the Piampaludo project has more potential.

47. CET proposes relatively high production rates in their mining plan (approximately 163,000 t/y), with a mine life of 90 years. To accomplish this rate, it is clear that the most viable excavation method suitable for the Piampaludo project would be open-pit mining. However, with Piampaludo's current circumstances, this mining method would not comply with the site's laws.

48. Thus, the Piampaludo Titanium project has been given a conservative classification for the technical feasibility, F2.2 on the F axis.

V. Conclusion and Challenges

49. According to the United States Geological Survey (USGS), Piampaludo's titanium deposit, located in Liguria, Italy, is one of the largest eclogite-hosted deposits in Europe, and of possible significant economic importance in the near future (Figure VIII) [23]. The project demonstrates the potential for a substantial and long-lived production. Based on the estimated ore grades and tonnage of the Piampaludo titanium deposit, it has the ability to eliminate the titanium supply risks in Italy and across Europe (Table 5) [23].

50. However, social and environmental concerns have forced the Piampaludo project into a hiatus and not progress. The opposing associations, municipality, and neighbouring communities have a fundamental opposition to mining in Piampaludo, based on the elevated risks associated with disturbing the natural landscapes and ecosystems of the park.

51. The Piampaludo project was classified according to UNFC to highlight the contingencies linked to it. This report demonstrates the application of UNFC to an exploration project using public information. UNFC addressed all issues related to the Piampaludo titanium deposit. UNFC is a resource classification tool that gives stakeholders information on the project's maturity.

52. The Piampaludo classification as an E3.2F2.2G3+G4 project according to UNFC provides an evaluation of titanium quantities and the project maturity status based on the available public information. With reference to UNFC-2019, the given classification category renders the Piampaludo project under the "Non-Viable Projects" class, and the "Development Unclarified" sub-class (Figure IX). The assessed sustainable aspects tied to the Piampaludo project are determined with respect to the permits granted by the Ligurian municipality to CET.

53. The information provided in this document infer that garnet could be produced as a potential by-product to titanium from the Piampaludo project. In line with the UNFC, by-products are to be classified separately, meaning that other considerations should be taken into account in terms of value addition, processing methods, and environmental impact. However, the Piampaludo titanium project is currently classified as non-viable, making the classification of garnet as a by-product irrelevant. In the event where titanium production becomes viable, then garnet is required to be classified separately using UNFC.

54. UNFC is a principles-based system, meaning that the end user is required to incorporate these principles even in the circumstances of less than ideal information. A more fulsome UNFC classification process would require more complete information from the industry's exploration activities, which have not been not made public for this classification. However, despite these limitations, the information used in this case study can define a classification sufficient for the mineral inventory of the Liguria region. This case study of the classification of the Piampaludo Project using UNFC is also intended as educational material for the application of UNFC.

Figure VIII
European titanium mineral deposits [23]

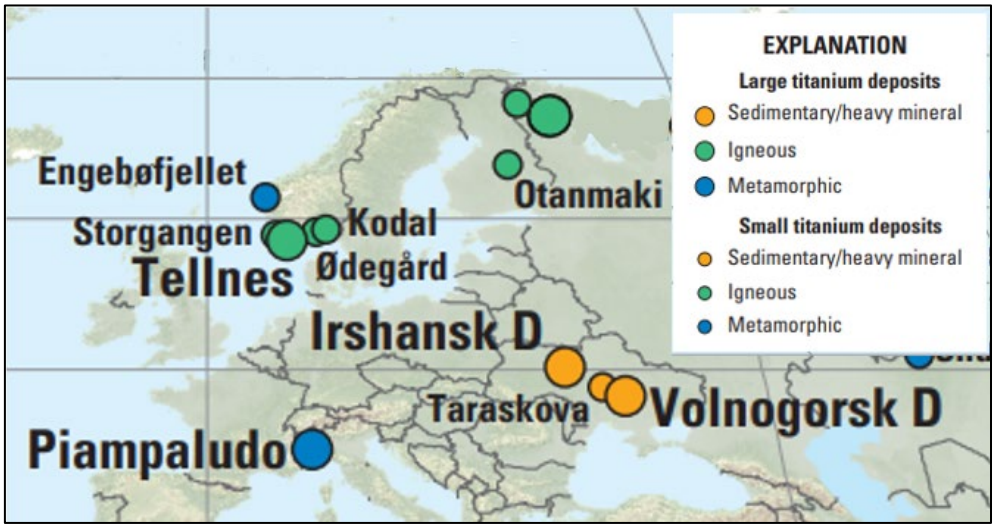
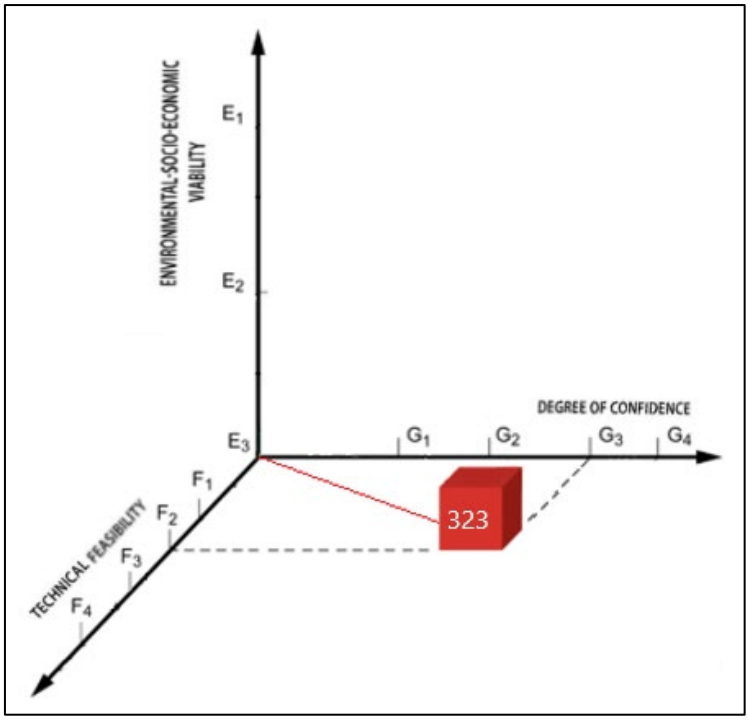


Table 8
Titanium mineral resources of Europe for ilmenite and rutile [23]

Country	*Deposit type*	*Deposit class*	*Contained TiO_2 by primary ore mineral (million Mt)*	
			Rutile	*Ilmenite/ titanomagnite*
Italy[a]	Rutile in eclogite	Metamorphic	9	-
Norway	Gabbro/anorthosite	Igneous	-	238
Norway	Rutile in metamorphic/ metasomatic rocks	Metamorphic	61	-
Ukraine	Heavy-mineral sands	Sedimentary	0.5	~14

[a] Pertaining solely to Piampaludo titanium deposit.

Figure IX
3D representation of the UNFC classification for the Piampaludo Project



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