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EXTRACTIVE WASTE MANAGEMENT: A NEW TERRITORIAL AND INDUSTRIAL APPROACH IN CARRARA QUARRY BASIN

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EXTENDED ABSTRACT

L'approvvigionamento di materie prime è essenziale per garantire lo sviluppo economico dei paesi europei; la loro disponibilità, tuttavia, risulta essere limitata, sia per la crescente domanda sia poiché le riserve naturali sono esauribili (e spesso, soprattutto per quanto riguarda le Critical Raw Material, i giacimenti si trovano in paesi extra EU). Stante queste premesse, l'Europa risulta essere fortemente interessata ad una politica che miri alla "conservazione delle risorse naturali", andando al contempo ad intervenire con azioni programmatiche nell'ambito del recupero di materie prime seconde (anche critiche) dai rifiuti. D'altro canto, gli scarti di cava rappresentano un enorme spreco di risorse e causano, di fatto, un incremento dei costi, economici e ambientali, connessi con la loro gestione e con la gestione delle discariche di cava. Una parte significativa di tali scarti può essere considerata una riscorsa preziosa, ma spesso sprecata a causa di pratiche di recupero non efficienti (legislazione poco chiara e generale mancanza di dati certi). Una grande quantità di rifiuti può essere recuperata come sottoprodotto o materia prima seconda, grazie al miglioramento dei processi produttivi, da una parte impostando in modo più sostenibile l'attività di coltivazione, dall'altro prevedendo di impiegare le varie frazioni di scarto prodotto. La pianificazione, sia dell'attività estrattiva sia della fase di trattamento, va ripianificata, ridefinendo, già a monte del processo, quali mercati possono essere interessati ai sottoprodotti in uscita. Unitamente a tale "cambiamento di prospettiva", che riguarda principalmente le attività in essere, bisogna pianificare e programmare il recupero dei materiali presenti nelle vecchie discariche.

In Italia, una grande quantità di scarti di cava sono stati e sono tuttora oggetto di messa a deponia presso le discariche di cava. Va sottolineato come, nel 2014, l'industria estrattiva (cave e miniere) si sia nuovamente piazzata al secondo posto per ciò che concerne la produzione di rifiuti (28.1% o 703 milioni di tonnellate considerando l'UE-27), subito dopo i rifiuti da costruzione e demolizione, saldamente al primo posto. Tali materiali possono rappresentare una grande risorsa integrativa per l'approvvigionamento di materie prime seconde.

Ad oggi, diversi produttori di lapidei, sia da rocce carbonatiche che silicatiche, sono interessati allo sfruttamento degli scarti prodotti: esempio emblematico è il potenziale sfruttamento di scarti provenienti dalla coltivazione del marmo di Carrara. Il bacino di Carrara è rappresentato da un centinaio di cave che coltivano diverse tipologie di marmo: dallo statuario ai colorati. La produzione di rifiuti si può riassumere in: 80 Mm^3 di scarti presenti nelle vecchie discariche di cava (*ravaneti*) e 3 Mm^3/anno di scarti fluenti provenienti da attività estrattive. Attualmente solo lo 0,5 Mm^3/anno di scarto viene sfruttato per la produzione di materie prime seconde, principalmente quale carbonato di calcio, praticamente puro, da impiegare per la produzione di materie plastiche, carta, nell'industria farmaceutica, etc.

Nel 2015-2016 è stata avviata una prima ricerca congiunta tra la Società Apuana Marmi s.r.l., poi confluita in Carrara Marble Way s.r.l, l'Università di Torino e la Società SET s.r.l., al fine di valutare le potenzialità di recupero dei materiali giacenti presso le discariche di cava. Tale ricerca ha riguardato una prima caratterizzazione di alcuni campioni rappresentativi provenienti da due bacini produttivi: Calocara e Lorano. I materiali campionati in situ e preparati presso il "Laboratorio di trattamento dei soliti e preparazione campioni" del Dipartimento di Scienze della Terra, Università di Torino, sono stati analizzati al fine di valutare le caratteristiche fisiche e minero-petro-geochimiche degli stessi. In particolare sono state eseguite analisi quali: distribuzione granulometrica, limiti di Atterberg, valutazione coefficiente Los Angeles, resistenza al gelo-disgelo, indice di forma ed appiattimento, analisi geochimiche ed analisi mineralogiche.

Sulla base dei primi risultati è stato possibile individuare alcuni potenziali campi di recupero: eg. produzione di asfalto, cemento, gesso, gomma, sigillanti, carta, vernici, plastica, etc. Altre applicazioni potenziali come sottoprodotti sono: aggregati per calcestruzzo a basse prestazioni, materiale da riempimento ed arginatura.

La sfida che bisogna pensare di affrontare, per il futuro, anche al fine di risolvere i problemi legati ai rischi connessi a dissesti idrogeologici e alla stabilità dei versanti nel bacino di Carrara, è il trattamento del materiale più fine presente presso le discariche, le c.d "terre". Si deve pensare, nell'ottica di un recupero della risorsa-scarto, di trovare idonei campi di applicazione anche per questi materiali considerati "poveri".

La presente ricerca fornisce alcune indicazioni circa lo stato dell'arte e le potenzialità di sfruttamento degli scarti di cava nella zona di Carrara, mettendo in evidenza le migliori pratiche produttive e i processi di recupero più efficienti. Verranno inoltre presentati i risultati preliminari relativi alla caratterizzazione dei materiali presenti presso le discariche di cava e ai campi di applicazione più promettenti.

ABSTRACT

Raw Materials, whose availability is increasingly under pressure, are essential for the EU economy: Europe is strongly interested in "resource preservation" and, furthermore, several researches are focused on the recovering of Critical Raw Materials and aggregate supply from landfill ("waste recycling"). On the other hand, quarry waste represents an enormous loss of resources and causes economic and environmental cost increase due to waste management and landfill activities. A significant part of quarry waste is valuable, but often lost because of not efficient recovery practices (unclear legislation and general lack of data hamper). In 2014 the mining and quarry industry represented the second most important sector (after C&DW) in terms of waste quantities produced in the EU-27 (28.1% or 703 milion tons: Eurostat, 2017).

A great deal of waste can be regained as valuable raw materials by the enhancing of quarry waste recovery processes to obtain Secondary Raw Materials (industrial minerals, aggregates, etc.).

In Italy large amounts of quarry waste have been and still are dumped. Such materials can represent a great alternative resource for Secondary Raw Material exploitation. Several dimension stone quarries, both from carbonate and silicate rocks, are interested by quarry waste exploitation: a noticeable example is the potential exploitation Carrara marble waste. The Carrara quarry basin is represented by one hundred quarries for colored and white marble exploitation. The waste production can be summarized in: 80 Mm^3 waste present in old quarry dumps (Ravaneti) and 3 Mm^3/y of waste from quarrying activities. At present only 0.5 Mm^3/y of quarry waste is exploited for Secondary Raw Material production.

On the basis of the grain size and chemical characteristics, several applications as SRM are possible: e.g. asphalt, cement, plaster, rubber, sealants, paper, paint, plastic, etc…. Other potential applications as by-products are: aggregate for concrete and crushed materials for embankments and armour stones. Moreover, the big chance for the future – in order to solve also hydrogeological and stability problems in the Carrara Basin - is treating "poor" material (called *terre*) to new, performing markets.

A preliminary research about Carrara Marble EW recovery was set up: two areas were sampled (Calocara and Lorano) and the sampled materials were analyzed to get information about size distribution, density, Atterberg limits, Los Angeles test, freezing and heat tests, flat and shape indexes, geochemistry, mineralogy. The first (preliminary) results shows a good attitude for quarry waste to be recovered.

The present research will show the state of the art and the potentiality of quarry waste exploitation in Carrara, highlighting best practices and efficient recovery processes (technologies and techniques).

Key words*: extractive waste, Carrara marble, waste management and recovery, secondary raw materials, circular economy*

INTRODUCTION

Quarrying is a very important industry in Italy especially for dimension stones and aggregates; in 2011 the overall turnover of the production chain (quarries, working plants, laboratories, shops, etc.) was nearly 40 billion € (almost 2% of the Italian Gross Domestic Product). In addition, Italian dimension stone exploitation during 2012 shows an export increment of 9.8% from 2011 and an import decrement equal to -6% (from 2011 to 2012) (Dino *et alii*, 2015a).

The production of dimension stones and aggregate is always associated to waste (Extractive Waste - EW) production, whose management is still a matter of concern. Indeed, in 2014 the mining and quarrying industry represented the second most important sector in terms of waste quantities produced in the EU-27 (28.1% or 703 milion tons), after C&DW (Eurostat, 2017). At present these materials are managed in different ways both locally and nationwide. The necessity to reduce the use of non-renewable natural resources and, at the same time, to minimise the negative impacts on environment, has led to an increasingly high interest in recovering and recycling. Nevertheless the principles to minimize waste production and to reuse/recycle waste materials are parts of the EU policy expressed in the Europe 2020 strategy to reduce-efficient Europe and EU Strategy for Sustainable Development (Dino & Marian, 2015; Loudes *et alii*, 2012). A sustainable and efficient EW management and recovery is based on the reduction of the environmental impact and on the improvement of their market and environmental acceptability.

In Italy large amounts of EW have been and still are dumped. Such materials can represent a great alternative resource for Secondary Raw Materials (SRM) exploitation. The Italian situation, where the policy about recycling activities is "in progress", is a paradigm of what the environmental consequences can be:

- overexploitation of the natural resources;
- potential environmental contamination (soil, water, air) for uncontrolled dumping or for not sustainable transport of raw materials;
- landscape alteration by the EW heaps.

The environmentally sustainable management of EW, which aims at the recovery and recycling of both clean and contaminated materials, would therefore help to reduce the pressure on natural resources, and potentially reduce the land take and the environmental and landscape contamination. Waste on-site/off-site recovery and suitable reuse, although recommended by E.U. guidelines and Italian Legislation, encountered a number of impediments, including: "NIMBY Syndrome", market suspicion towards the quality of recycled products, and also controversial interpretation of existing waste legislation. In the Northern Europe, territorial environmental agencies recommend the reuse of the treated matrix whenever possible instead of using natural materials considered as "non-renewable resources". A sustainable management of the land and of natural resources must be based on the overall organization of flows of materials and on the optimization of recycling activities, including the optimal use of each potential recycled product in the most profitable industrial sectors (Dino *et alii*, 2015b).

In Italy several dimension stone quarries, both from carbonate and silicate rocks, are interested by quarry waste exploitation: a noticeable example is the potential exploitation Carrara marble waste. Such materials are often disposed of in dumps, while they could be rather profitably recovered and recycled as SRM for: industrial minerals, high value products, aggregates, filler materials, etc.... The Carrara quarry basin is represented by one hundred quarries for colored and white marble exploitation. The waste production can be summarized in 80 Mm^3 waste present in old quarry dumps (*Ravaneti*) and 3 Mm^3/y of waste from quarrying activities. At present only 0.5 Mm^3/y of EW is exploited for SRM production.

Several researches investigated the recovery of limestone and marble waste (Careddu & Dino, 2016; Careddu *et alii*, 2014; Careddu *et alii*, 2013; Gencel *et alii*, 2012; André *et alii*, 2014; Galetakis *et alii*, 2012; Marras *et alii*, 2010; Felekoglu, 2007).

The present paper aims at presenting the first preliminary results arising from a research about EW management and recovery from Carrara marble quarry basin (Ravaneti: coarse materials and "terre").

MATERIALS AND METHODS

Geological setting of the Carrara area

The Carrara quarry basin is located in a ca. 25 x 15 km wide area in the hinterland of Carrara, in the northern most part of Tuscany (Italy) (Fig. 1). The basin, exploited for dimension stones since the antiquity, is divided into three sub-basins (NW to SW: Torano, Fantiscritti and Colonnata sub-basin) and occurs within the Apuane Alps in the Northern Apennines.

From the geological point of view, the Northern Apennines are a thrust and fold belt formed, during Tertiary, as a consequence of the eastward overlapping of the internal Liguride Units (of oceanic affinity) on the external Tuscan and Umbro-Marche Domains. Within the Apennine chain, the Apuan Alps represent a tectonic window where the underlying metamorphic complex crops out. Such a complex is composed of two units: the geometrically lower Apuane Unit ("Autochtonous" *Auct*.), which crops out over a NW-SE trending elongated area ca. 20 x 10 km wide, and the overlying Massa Unit, which occurs as a relatively narrow, elongated belt at the inner border of the Apuane Unit (Fig. 1). The Apuane Unit is composed of a Paleozoic basement (affected by a greenschist-facies metamorphic event of ercynian age) and a Mesozoic (upper Triassic – Oligocene) metasedimentary cover which includes terrigenous rocks (conglomerates to different types of siliciclastic deposits) and a variety of carbonatic rocks, transformed to marbles by the alpine-age metamorphic overprint, characterized by peak temperatures of around 350-450°C at pressures of 0.4-0.8 GPa (Di Pisa *et alii*, 1985; Franceschelli *et alii,* 1986; Molli *et alii*, 2000).

The Massa Unit is also composed of a paleozoic basement which is overlaid, however, by a sedimentary cover of Triassic age only. Such a cover includes several types of siliciclastic and (in the upper part) carbonatic rocks, and is characterized by the occurrence of interbedded middle Triassic (meta-) volcanics of alkaline affinity. P-T conditions of the alpine metamorphism are slightly higher than those inferred for the Apuane Unit (Franceschelli *et alii*, 1986; Jolivet *et alii*, 1998; Franceschelli & Memmi,1999; Molli *et alii*, 2000).

As pointed out by several Authors (Carmignani *et alii*, 2005, with refs.), in addition to the famous marbles, other types of ornamental stones are, or have been, exploited in the Apuane Alps. They include metabreccias and metarudites (mostly not pertaining to the same stratigraphic horizons of the marbles), *cipollini* (generally corresponding to calcschists, clearly younger than the marbles) and metasandstones, metasiltites and phyllites, related to the Upper Oligocene flysch. The famous Carrara marbles only correspond, however, to the Lower Liassic Marble formation of the Apuane Unit sequence.

Quarry exploitation: past and present activities

Carrara Marble represents a very historical material: its exploitation is known since Roman time. Quarry exploitation was conducted with traditional systems up to the 90s; marble production was destined to national and international customers, with a low-medium production rate and a "not-industrial" approach. Due to this quarry management approach, *ravaneti* (waste material from marble exploitation, Fig. 2) was natural

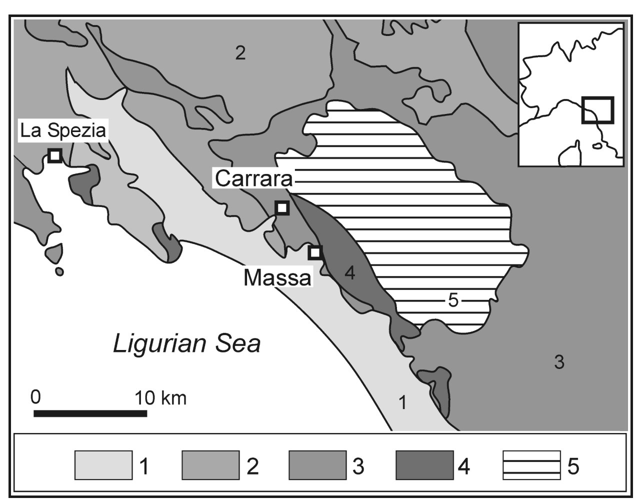

Fig. 1 - Tectonic sketch-map of the Northern Apennines in the Carrara area. 1: Pliocene and Quaternary deposits, 2: Ligurian Units, 3: Tuscan Units, 4: Massa Unit, 5: Apuane Unit ("Autochtonous" auct.). Simplified from Carmignani *et alii, 2006*

Fig. 2 - Scatch of Carrara quarry basin and the large "ravaneti"

part of the landscape, generally safe as for the slope stability, sometimes characterized by a "green" environmental rehabilitation and without any different destination. Indeed, some of them are defined *ravaneti storici* (historical quarry dumps). In the past, nobody pointed up about hydrogeological impacts, slope stability and landscape issues: the waste volume increased and increased, the size of blocks were different depending on the different working era (also technologies changed during the time: at present, modern cutting systems generate more fine materials), but safety and environmental needs were not so strong, in comparison with the importance of maintaining and implementing exploitation and working activities.

In the last 20-25 years, something has changed: foreign markets (China, Emirates, Russia, Turkmenistan especially) started to request enormous volumes of Carrara marble to satisfy their fast and intensive urbanistic growth. So that the amount of EW has become larger and larger, generating problems in quarry management and activities (landslides, flooding roads and inhabited urban area). In the meantime, big Companies, leader in Calcium Carbonate production, built dressing plants to recycle material present in "ravaneti", creating new jobs and productive development: from EW to precious industrial products. But they are not "quarryman", so they do not care and manage Carrara quarries. These industries aim at recovering only the pure calcium carbonate under-size coming from quarries, but not the complete waste/resource; so that a great part of the waste (the worst in quality) remain in the quarries, causing one of the main, actual, problem to Carrara quarrying activity.

In 2011, due to the necessity to manage in a sustainable way Carrara EW facilities, SAM Group was constituted; the aim of the company is to monitor the *ravaneti* areas, trying to find a solution for the management of EW. At the beginning with a basic "safety and environmental" check about the waste recovery (carried out by external companies), then changing to a R&D approach. Some years later, on the 26th of October 2016, Carrara Marble Way srl (CMW), a new.co. grouping 40 Carrara & Massa quarry companies (including SAM group), was born to manage directly "Ravaneti", in order to create a complete production-line of materials, from the best to the poorest quality. At present a Business plan is in progress, aiming at programming the activities for the systematic recovery of each "waste" fraction present in the *ravaneti* (not only the best quality; Fig. 3, 4). Such new planning and exploitation phase needs the employment of modern and safe technologies, to remove and manage waste, also for creating larger spaces for workers and machineries.

Materials and performed analysis

A preliminary research about Carrara Marble EW recovery was set: two areas were sampled (Calocara and Lorano, Fig. 5, 6), which can be considered representative of the 70 quarries present in the Carrara area. Some data about Carrara marble characteristics are reported in Tab. 1.

Fig. 3 - The big "grids" usually employed for the first selection in the quarry

Fig. 4 - A storage area at "Ponti di Vara"

Physical characteristics	Value
Bulk density	*2688 kg/m^3*
Simple compression strength	*1209 kg/cm^3*
Compression strength after freezing	*1181 kg/cm^3*
Indirect Tensile Strength (Brasilian test)	*174 kg/cm^3*
Impact strength test	*73.8 cm*
Moisture absorption (by weight)	*0.16%*

Tab. 1 - Carrara marble physical-mechanical characteristics (on average)

The sampled materials (Fig. 7) were analyzed to get information about physical, chemical, mineralogical and petrographic characteristics.

As for the physical characteristics the test performed were: size distribution, bulk density, Atterberg limits, Los Angeles test, freezing and heat test, flat and shape analysis, fine particles content.

For each area (Lorano and Calocara) tests have been performed for three different classes:

- 0.5-4 mm
- 0-25 mm
- 0-150 mm

The number of tests for each sample or mix is specified in Tab. 2.

For the mineralogic and geochemical characterization of the material, the following analyses were performed:

- *petrographic analysis*. The petrographic study, under polarized-light optical microscopy, was performed on the coarse-grained material in order to characterize the texture and mineralogical composition of the primary rock-type.
- *X-ray powder diffraction (XRPD) analysis*. Data were collected in the 3-70° 2θ range at room temperature using an automated Siemens D-5000 diffractometer with a θ/2θ setup in Bragg-Brentano geometry, using graphite monochromatized Cu-Kα radiation and a zero-background flat sample holder. Qualitative mineralogical analyses were obtained with the Diffrac Plus (2005) evaluation package – EVA 11,00,3. Analyses were performed on the <0.125 mm fraction after sieving.
- *Whole rock geochemical analyses*. Analyses were obtained using the ICP-AES technique; a lithium borate fusion of the sample prior to acid dissolution and analysis was adopted in order to solubilize also highly refractory phases. Analyses were performed on both the unsorted material and the <0.125 fraction after sieving.

RESULTS AND DISCUSSION

As introduced, several samples from Carrara EW were analyzed (three different classes both for Calocara and Lorano area) to evaluate their physical, geochemical, mineralogical and petrographic characteristics. The test performed, though preliminary, are useful as basis to evaluate which kind of reuse seems to fit better. The laboratory phase was conducted from July 2015 to March 2016.

Fig. 5 - Calocara "ravaneti"

Fig. 6 - Lorano "ravaneti"

Fig. 7 - Selection and sampling

Laboratory tests results: physical analysis

The results of physical tests on Lorano and Calocara EW samples are resumed in Tab. 3. The samples C 0.5-4 and L 0.5-4, according to grain size distribution analyses, are sand with a

Sample Name	Grain size analyses	Atterberg limits	Density	Los Angeles test	Freezing and heat test	Shape index	Flat index
C 0.5-4	1	-	3	-	-	-	-
C 0-25	1	3	3	1	3	1	1
C 0-150	1	3	2	1	3	1	1
L 0.5-4	1	-	3	-	-	-	-
L 0-25	1	3	3	1	3	1	1
L 0-150	1	3	2	1	3	1	1

Tab. 2 - Summary table of performed geotechnical tests on the sampled materials. Legend: C (Calocara); L (Lorano)

Sample Name	Grain size distribution	Atterberg limits: Liquid Limit WL %	Atterberg limits: Plastic Limit WP%	Density (on average)	Los Angeles test %	Freezing and heat test (on average) %	Shape index (%)	Flat index (%)
C 0.5-4	Sand weakly gravelly	-		2.55		-	-	-
C 0-25	Sandy gravel weakly silty	Not plastic		2.59	68	0.8	16.5	27.2
C 0-150	Gravel weakly sandy-silty	Not plastic		1.96	69	0.3	17.4	19.5
L 0.5-4	Sand weakly gravelly	-		2.46		-	-	-
L 0-25	Sandy gravel weakly silty	Not plastic		2.40	43	0.4	21.9	25.7
L 0-150	Gravel weakly sandy-silty	Not plastic		1.98	42	0.3	28.8	29.5

Tab. 3 - Summary table of the physical tests results

small part of gravel, the samples C 0-25 and L 0-25 are gravels with small sand and weak silt contents, and the samples C 0-150 and L 0-150 are gravel with weak sand and silt contents.

The Atterberg limits results (C0-25; C0-150; L0-25; L0-150) indicate that the materials are not plastic. The LA value for Calocara samples are too high, therefore the materials do not fit to aggregate production; the ones for Lorano samples are lower, but they seem to fit only few application as aggregate (low grade applications).

The first results (grain size distribution, LA test, Freezing and heat test and Atterberg limits, Tab. 3) show an attitude for EW to be recovered and the most promising recycling activities are: crushed materials for enbankments and armour stone.

Laboratory tests results: petrographic, geochemical and mineralogical analyses

The petrographic analysis shows that the primary rock from Calocara is an extremely pure, relatively coarse-grained marble, showing a granoblastic texture (Fig. 8). This is in agreement with the geochemical data (Tab. 4): the whole-rock composition of the same rock is, in fact, close to that of pure calcite, only showing very low MgO, SiO_2, Al_2O_3 and Fe_2O_3tot contents. Compared with the primary rock-type, the <0.125 fraction still shows an almost pure marble composition, but displays a low to moderate increase of Al_2O_3 (0.12 to 0.3 wt. %), Fe_2O_3 (0.07 to 0.14 wt. %), MgO (0.74 to 2.13 wt. %) and SiO_2 (0.7 to 1.4 wt. %). These data are in agreement with the XRPD spectrum on the same fraction, which only shows the peaks of (Mg-) calcite. Summing up, the geochemical, XRPD and petrographic analyses show that compared to the primary rock-

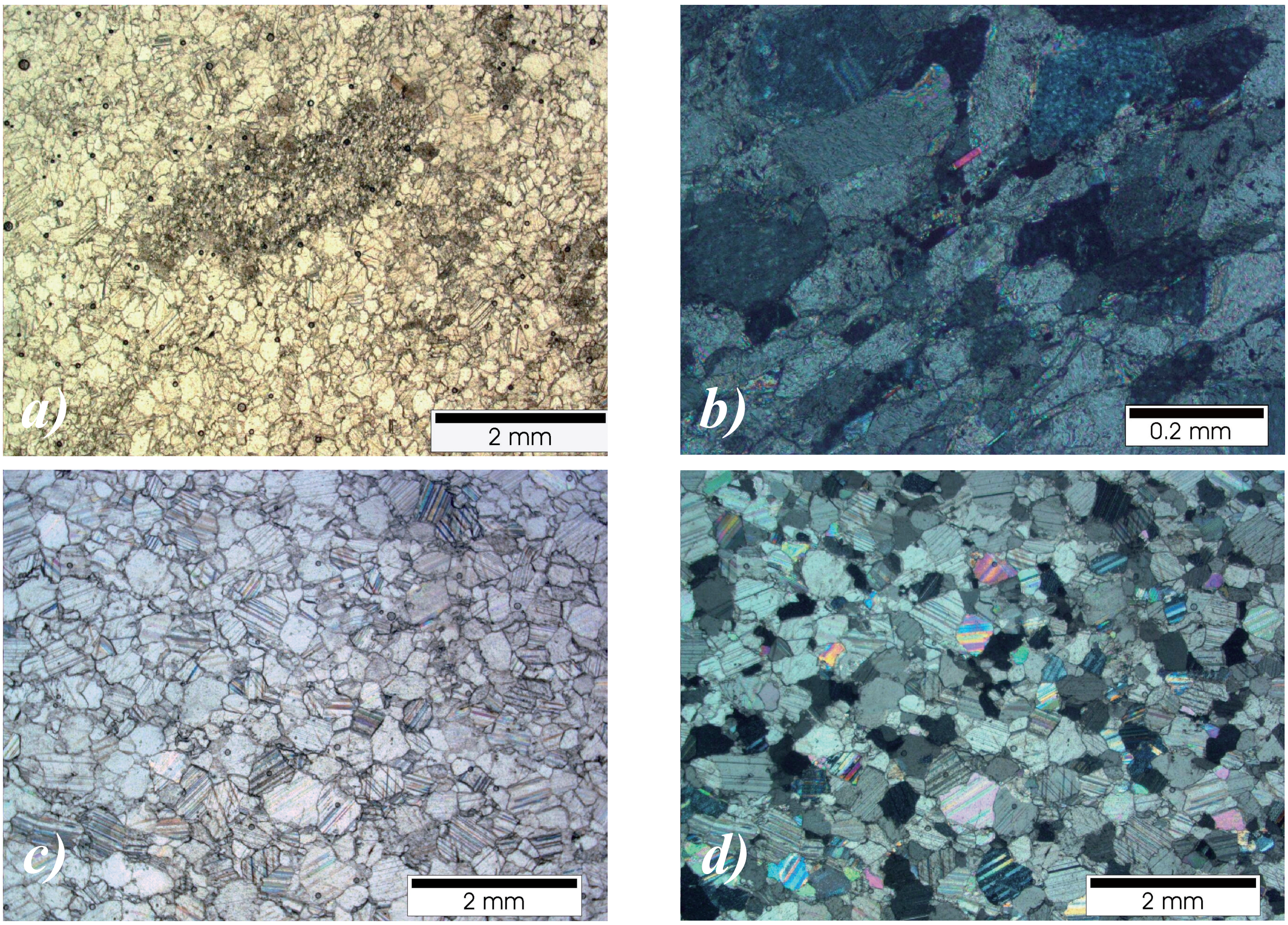

Fig. 8 - Typical aspect of the marbles under the microscope. a): Lorano marble, characterized by carbonate with variable grain size; the "dusty" grains are composed of calcite with higher Mg content. The same rock at higher magnification and crossed polars; b) shows fine-grained domains where elongated calcite crystals are associated with minor white mica (small red lamella). c): Calocara marble with granoblastic structure; d): same view under crossed polars

type (which is a high purity marble), the fine-grained portion is slightly enriched in quartz (<1 vol. %), white mica (<1 vol. %; possibly partially chloritized) and Fe oxides/hydroxides (<0.5 vol. %).

The analyzed sample from Lorano is also, under the microscope, an almost pure granoblastic marble which is, however, characterized by variable grain size; particularly, carbonate intergrowths occurs which show a dusty appearance, likely composed of Mg-calcite. Finer-grained, iso-oriented domains (few hundred microns thick) occur composed of xenoblastic calcite associated with very minor fine-grained white mica (Fig. 8). The same domains also contain very fine-grained disseminations of Fe-oxides/hydroxides. Whole-rock geochemistry of the same material (Tab. 4) shows, apart from CaO, very low MgO, SiO_2, Al_2O_3 and Fe_2O_3tot contents. By comparison, the <0.125 mm portion –though still showing a composition very close to pure marble- displays a significant increase in SiO_2 (0.32 to 2.63 wt. %), Al_2O_3 (0.04 to

Sample	Lorano marble	Lorano <0.125 mm	Calocara marble	Calocara <0.125 mm
wt. %				
SiO_2	0.32	2.63	0.74	1.41
TiO_2	0.01	0.04	0.01	0.02
Al_2O_3	0.04	0.89	0.12	0.30
Fe_2O_{3tot}	0.04	0.40	0.07	0.14
MnO	<0.01	0.02	<0.01	0.01
MgO	0.72	0.79	0.74	2.13
CaO	56.10	52.60	54.10	53.00
Na_2O	<0.01	<0.01	<0.01	<0.01
K_2O	<0.01	0.21	0.01	0.06
P_2O_5	<0.01	0.02	0.04	0.02
Cr_2O_3	<0.01	<0.01	<0.01	<0.01
BaO	<0.01	<0.01	<0.01	<0.01
SrO	0.01	0.01	0.01	0.01
LOI	42.00	42.10	43.00	42.80
Total	*99.24*	*99.71*	*98.84*	*99.90*

Tab. 4 - Geochemical analyses

0.89 wt. %) and K_2O (<0.01 to 0.21 wt. %); the MgO content is instead nearly constant. These data are in good agreement with the XRPD spectrum on the same fraction, which shows the occurrence of the (Mg-)calcite and a low cristallinity white mica. Summing up, the geochemical, XRPD and petrographic analyses of the Lorano material show that compared to the primary rock-type (a high purity marble), the fine-grained portion is slightly enriched in quartz (≈ 1.5 vol. %), white mica (≈ 2 vol. %) and contains very small amounts of Fe and Mn oxides/hydroxides (<0.5 vol. %).

These data clearly need to be confirmed by other analyses. However, the results obtained so far from the geochemical, mineralogical and petrographic characterization show that the analyzed samples may represent high value products (the materials being composed of nearly pure $CaCO_3$), that it could be used as filler for paper, rubber, paint, plastic, etc. production.

CONCLUSIONS

The results obtained during the present research are promising. In particular, the first results arising from the physical characterization show an attitude for Carrara EW to be recovered as crushed materials for enbankments and armour stone. If we consider also the results obtained from the mineralogic and geochemical analysis it has to be highlighted that these materials, being composed of nearly pure $CaCO_3$, could find a proper application in high value products, as: filler for paper, rubber, paint, plastic, pharmaceuticals, etc… (Prescott & Pruett, 1996). Considering that the global economic crises has affected construction and building sectors, it appears more strategic to focus on the uses of $CaCO_3$ in high value-added products.

The data obtained from the research need to be confirmed by other analyses: a systematic characterization of EW present in the different EW facilities has to be programmed. R&D will be strategic to solve problems connected to quarry, dumps and landscape management.

In 2014-2015 a new Regional Law changed historical standards to plan and manage quarries and processing plants, introducing environmental and territorial constraints and new obligations for activities; new balance will have to be found, in order to continue each activity. Furthermore, on the basis of a recent updating of local guidelines (ARPAT indication Feb. 2017), these problems have risen more and more, causing lot of troubles connected both to *Carrara Ravaneti* (considered as EW facilities to manage more strictly then before) and to residual sludge coming from marble stone working activity.

The cooperation within private Companies, Research Centers (Universities of Torino, Firenze and Pisa) and Local Authorities is fundamental to reach the target, in term of experimentation of new products. Every actor involved, on the basis of proper expertise, will study the best practice to recover and reuse this resource: eg. civil works and infrastructure, building industry, agronomy, high-tech, etc….

At a wider scale, if the quarry industries aim at guaranteeing the systematic and convenient recovery of EW as SRM, a change in exploitation and working activities has to be planned, in order to have a disposal area for marble scraps, which should be projected as a centre for stone materials aimed at secondary processing. Furthermore, to produce new products, it is necessary to think about several actions, such as:

- The right selection of the different potential SRM to be sent to a proper dressing plant (in particular for high value products).
- A proper treatment depending on the kind of reuse. A treatment-activity protocol should be forecasted in order to produce each New Product. The materials to be used as crushed material for embankment or as armour stone must be separated from the high quality ones in order not to pollute their quality.
- A market ready to accept New Products obtained from EW treatment. In this case, it is necessary to inform and sensitize the civil society about the necessity to accept and use products coming from "waste" treatment (End of Waste Criteria).

The interest for a systematic recovery of EW should be recognized by both private and public bodies as a mean to promote environmental and territorial protection and conservation of non-renewable resources. It could represent an important alternative (integrating) source as a substitute to the exploitation of virgin materials. Waste has to be considered as Future Resource and Waste facilities has to be considered as "new ore-bodies" to exploit following the mine approach principles. In this sense, a recent H2020 project, named SMART GROUND has been funded. The project is intended to foster resource recovery in landfills by improving the definition of new and integrated data acquisition methods and standards (tested on selected pilot sites). It gathers data from existing databases and collects new information from municipal, industrial and mining waste streams across EU landfills (Dino *et alii*. 2016; 2017). The chance to add the data collected from Carrara Marble EW in SG platform, as testing area, is presently under consideration.

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