Dereliction problems from exploitation of residual soil and ornamental stone at ubatuba, São Paulo State, Brazil

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Abstract: The municipality of Ubatuba (North Coast of São Paulo State, Brazil) is highly regarded for its natural landscape. It encompasses the Serra do Mar Mountain Range covered by large remnants of Atlantic Forest (approximately 80% of the municipal territory corresponds with a nature reserve state park) and an encroached coastline with sandy beaches and bays. Until the early 1990's intensive exploitation of residual soil and ornamental stone for civil construction took place in a context characterized by lack of planning and regulation. This resulted in highly adverse environmental impacts and a number of derelict and abandoned sites, which has led the authorities to enforce a virtual halt to mining activity over recent years.

This paper describes the early stages of an inter-disciplinary investigation that has been conducted to formulate strategies for reclamation and redevelopment of these sites. It attempts to address three key issues: 1) environmental recovery; 2) reduction of hazards; and 3) economic activity. The materials subject to mineral exploitation are derived from the Precambrian crystalline basement of the area (mostly consisting of granites and gneisses). The residual soil is considered an important asset for urban development as it has been used as fill in the construction and maintenance of roads, housing and engineering works in general. Tropical climatic conditions associated with the local hilly landscape gave rise to thick (10-30m) weathered profiles so that exploitation of these deposits required only very simple technology. The ornamental stone (granite bearing pyroxene, commercially known as Ubatuba green granite) is predominantly exploited in the form of rock boulders scattered on hill slopes or within the soil mass. According to previous inventories, there were 33 mining sites in 1982 (18 operational, 11 abandoned). In 2004, 106 sites were registered with only one in operation as a source of fill. Preliminary assessment of 95 of these sites was based on the following criteria: land stability, degree of re-vegetation, scenic aspects, and potential for redevelopment. 39 sites were pre-classified as derelict, 22 as partially recovered, 34 as recovered, and 1 in redevelopment (for landfill). Land instability problems were observed in 51 sites, and these included high rates of soil erosion, landsliding, block falls, water accumulation at the surface and mudflows. Nine sites were pre-classified as hazardous areas. The relevant regulatory framework and issues connected with the licensing of mining operations, economic value of remaining mineral, and the relation of mining activities to existing regional and urban plans were also considered.

Résumé: La ville de Ubatuba est bien regardée pour son paysage naturel. Celle-ci renferme la Cordillère de la Côte (*Serra do Mar*), couverte par des aires qui sont des restes de la Forêt Atlantique (dont environ 80 % du territoire comprends une réserve de la nature - le Parc Serra do Mar), qui est côtoyée par un littoral entaillé par des petites baies et des plages sablonneuses. Jusqu'au début de la décennie 90, les exploitations du sol résiduel, des pierres de taille et des granulats rocheux ont été faites d'une façon sans planification et aucun cadre réglementaire. Cette situation a entraînée des impacts hautement adverses et un nombre de chantiers abandonnés, ce qu'il a fait des autorités responsables à obliger l'arrêt des activités d'exploration minière pendent les dernières années.

Ce travail présente les premières stages d'une investigation interdisciplinaire qui a été conduite pour formuler les stratégies de relèvement et redeveloppement de ces chantiers. On essaye ici d'addresser trois problèmes principaux : 1) le relèvement environnemental ; 2) la réduction des risques ; et 3) l'activité economique. Les matériaux sujets d'exploration minière sont derivés des terrains précambriens constitués par des granites et des gneisses. Le sol résiduel de ces roches est une importante ressource pour le développement urbain car il avait eté très utilisé comme matérial de remplissage dans la construction civile (par example, entretien d'autoroutes et construction d'immeubles). Les conditions climatiques tropicales, en association avec les paysages accidentés, ont suscitée des profils de sol avec épaisseurs entre 10 – 30 m, donc l'exploitations de ces gisements ont demandée une très simple technologie. La pierre de taille est majoritairement exploitée par le partagement des blocs rocheux affleurents sur les colines ou immergés dans la masse du sol. Des inventaires précedents rapportent qu'en 1982 il y avait 33 chantiers miniers (18 en opération et 11 abandonnés). Pendant 2004, 106 chantiers ont eté enregistrés, mais seulement un était en marche comme source de matériaux de remplissage. L'évaluation preliminaire de 95 de ces chantiers a eté basée sur les critères suivants: stabilité du terrain, degrée de re-végétation, aspect scénique, et potentiel pour re-développement. 39 chantiers ont eté pre-catégorisés comme abandonnés, 22 comme partiellement récuperés, 34 comme récuperés et 1 comme un re-développement en marche (pour site de dépôt de déchets). Problèmes a l'égard d'instabilité du terrain ont eté observés dans 51 chantiers, qui incluent des hauts taux d'érosion du sol, glissements, écroulements des blocs rocheux, accumulations de l'eau en surface et torrentes de boue. Neuf chantiers ont eté catégorisés comme dangereux. La structure réglementaire pertinente et les sujets concernés aux permis d'opération minière et aux permis environnementaux ont eté aussi considerés.

Keywords: abandoned mines, soils, reclamation, environmental impact, geological hazards, slope stability.

INTRODUCTION

The north shore of the State of São Paulo (Southeast Brazil) is considered to be a centre for regional development, especially for tourism and leisure activities, as well as for the local infrastructure (transportation, energy distribution etc), thus placing major demands on natural resources. The municipality of Ubatuba (Figure 1), comprising an area of 748 km² (131 km² of urban use), population of approximately 67,000 inhabitants, and demographic growing rate of 5.5% per year (the highest of the State), is particularly relevant in ecological terms. It hosts an encroached rocky coastline with sandy beaches and bays bordered by the Coastal (Serra do Mar) Mountain Range, which is covered with well-preserved and important remnants of Atlantic Forest. Approximately 80% of municipal territory lies within a nature reserve state park. In this sense, its territory is regarded as highly sensitive in relation to geodynamic and ecodynamic changes so that stringent land use restrictions apply in order to provide consistent policies towards ensuring sustainability.

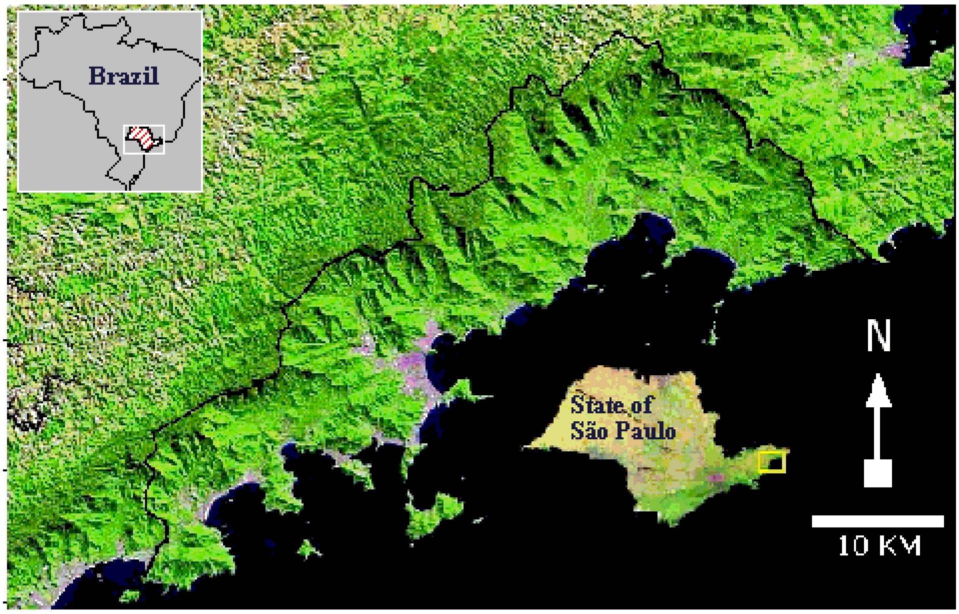

Figure 1. Location of the Municipality of Ubatuba in relation to the State of São Paulo and Brazil. Landsat ETM 7 satellite image (UTM projection, 23 Sº zone, approx. lower right corner coordinates = N 7390000 E 530000, SAD 69 datum). Municipal geopolitical boundaries as indicated. Note major shading with SW – NE orientation given by relief features (Coastal Mountain Range).

Mineral exploitation, particularly for aggregates, is considered to be strategic not only to the municipality but also for the whole region. Tropical climatic conditions associated with a hilly landscape gave rise to thick (10-30m) weathering profiles derived from Precambrian granitic-gneissic rocks. Residual soil (see Figures 5, 6, 7 and 9) has been widely used for civil construction, particularly road surfacing and fill for housing and commercial building. Ornamental stone (granite bearing pyroxene, commercially known as Ubatuba green granite) has also been exploited, predominantly in the form of rock boulders scattered on hill slopes or within the soil mass (see Figure 6). Combined exploitation of large volumes of residual soil and ornamental stone require only simple technology, and until the early 1990's it took place in a context characterized by lack of planning and regulation. This has caused highly adverse environmental impacts, such as deforestation, soil erosion, land instability hazards, scenic deterioration, pollution and disturbance of local water flow regime, which led the authorities to enforce a virtual halt to mining activity over recent years. However, lack of appropriate policies to promote land reclamation resulted in legacy of derelict and abandoned sites.

Despite previous (e.g. Silva *et al.*, 1977; Chiodi *et al.*, 1982; Bitar *et al.*, 1985; Braga, Fornasari & Soares, 1991; Silva, 1995), reclamation of these sites has turned into a complex issue involving the following aspects:

- There is significant regional demand for the residual soil (locally named as "saibro"), mostly to satisfy the real estate market and maintenance of road network;
- The low added value of the material (saibro) constrains economic activity to short distances between exploitation site and the place the material is going to be utilized, which may create difficulties for rational use of such a resource and implementation of controlling actions;
- Most of the municipality territory lies within designated nature conservation areas (Atlantic Forest). This includes areas in which advanced degradation of vegetation and wildlife have been reported (Melo *et al.,* 2003);
- Mining companies with high levels of organizational and technical expertise would not be interested in conducting mineral exploitation activity where only marginal profits are likely;

- Independent operators (miners) and small companies have been able to carry out low cost exploitation of residual soil (and ornamental stone), thus making sustainable profits. However there are many difficulties for such small entrepreneurs to comply with a range of technical and environmental requirements;
- The Public Attorney may take actions to force compliance with legal requirements for land reclamation after closure or long-term halting of mining activity;
- The State Civil Defence Board has a duty to manage risk caused by land instability in disused quarried sites.

Additionally, a recent study conducted by Melo *et al.* (2003), with reference to the whole State of São Paulo, observed that 60 % of reported cases of land dereliction in the north shore region are associated with former mineral exploitation activity, which is much higher than State's average of 23%.

The present paper describes the early stages of an inter-disciplinary investigation conducted to formulate strategies for reclamation and redevelopment (after-use) of these sites.

A total of 106 sites were registered in a first field survey carried out in 2004. At this time, there was only one site in operation as a source of *saibro* fill whilst 61 sites were considered to be fully or partially derelict (from the 95 sites visited and studied in some detail).

METHODOLOGY

In general terms, land reclamation on sites that have been subject to mineral exploitation, consists of actions to minimize environmental damage and which aim to re-establish conditions for natural balance and sustainability so reconciling former mined/quarried sites with their surroundings (Barbosa & Mantovani, 2000; Brollo *et al*., 2002). To be successful, strategies and programs for land reclamation need to consider physical and biological characteristics of the local environment as well as socio-economic factors. Aspects that must be considered carefully before any action for site reclamation is taken include vegetation and its interactions with fauna and ground characteristics, the kind of impact (e.g. visual), and the final goal of the reclamation.

Socio-environmental regeneration, in turn, involves not only land stabilization in geotechnical, vegetation and soil structural terms, but also in the definition of a new function (or use) for former mined/quarried (derelict) sites.

As suggested by Ferreira *et al*. (2005), management strategies for mineral exploitation in the municipality of Ubatuba require an integrated approach that involves different factors and considerations (see Figure 2), and in which three key issues must be addressed:

- Environmental recovery of a number of derelict sites (abandoned, unsightly)
- Reduction of hazards (land instability, erosion, flooded areas etc), particularly at those sites informally occupied by low income populations; and
- Rational production of building materials to properly respond to local needs.

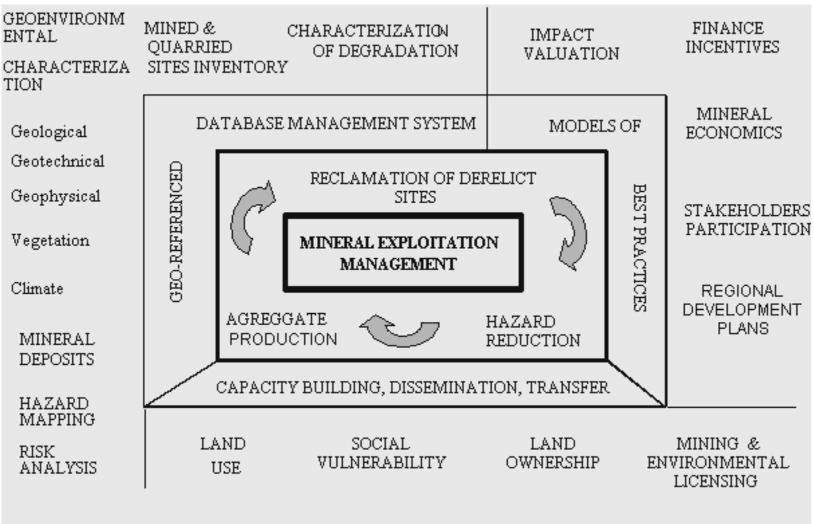

Figure 2. Schematic diagram of the integrated approach to be taken for mineral exploitation management at Ubatuba showing the main issues to be addressed (centre) and topics of interest to be studied.

The main questions arising from such an approach are the following: Which sites are critical in terms of environmental degradation? What are the adverse impacts and what is their magnitude and characteristics? Which reclamation procedures should be undertaken? What after-uses are feasible? What are the possible ways of funding or of encouraging reclamation? What economic value can be attributed to environmental impacts? How dereliction problems may be prevented from occurring again at this and other locations?

As suggested by Almeida (2002), a land reclamation program should be based on accurate assessment of factors that led to degradation/dereliction and site characteristics (biotic and non-biotic). This will be the major guidance to define strategies for reclamation, which will be rather dependent upon the intended after-use for sites (e.g. public amenities, nature and wildlife park, private and commercial buildings etc.). A number of approaches can be taken in combination in order to reduce or prevent geodynamic processes (such as erosion and landsliding), to promote retention of soil nutrients, and re-establishment of biodiversity. In geotechnical terms, physical stability of rocks and soils must be achieved with proper attention to reconditioning of the local drainage system. In soil-related and botanical terms, re-vegetation must be promoted and some soil fertility re-established.

A preliminary survey and assessment of a large number of derelict sites, and encompassing a diverse range of environmental characteristics, was carried out to determine impact magnitudes, complexity of the problems and to prioritize further investigation and actions. This included: (a) compilation and analysis of existing data (previous studies and records held by different authorities and organizations); (b) evaluation of mining and environmental licensing status of sites; (c) site visits and observations; and (d) pre-classification of sites in terms of environmental degradation, and land instability and potential hazards. The outcomes of such preliminary survey and assessment are presented here and considerations for follow-up work are also made.

Analysis of existing data

Silva *et al.* (1977) noted the first comprehensive studies of mineral resources of the region of Ubatuba. In the 1980's, a number of projects were conducted under the initiative of *SUDELPA* (State Development Agency for Coastal Regions) and these included: Mineral Exploration Planning in Coastal Areas (Chiodi *et al.*, 1982), Ornamental Stones (Macedo & Chieregati, 1982) and Technical Subsides for the Planning of Mineral Exploration Activity at the Municipality of Ubatuba (Campos & Bitar, 1984). These studies were furthered by the production of the Geotechnical Chart of Ubatuba (São Paulo State Government, 1989; Braga, Fornasari & Soares, 1991). These studies focused mainly on the economic activity of mineral exploitation in the region, though some environmental concerns were voiced in Chiodi *et al.* (1982) counter to the views of most others that mining and quarrying operations would supposedly not significantly interfere with the surrounding environment.

Awareness of the potential adverse impacts of aggregate mineral exploitation started in the late 1980's in the context of civil defence actions (hazard mapping and hazard control programs) promoted by the State Government (São Paulo State Government, 1988, 1989; Bitar, 1990; Silva, 1995). Ferreira (2003) produced an updated and geo-referenced inventory of mineral exploitation sites in the north shore region of São Paulo State, in which 101 records corresponded to sites mined and/or quarried for residual soil and ornamental stone in Ubatuba. In this study, previous and new data were analyzed from an environmental viewpoint, i.e. further mineral exploitation in the municipality should be prioritized and reconciled with reclamation of abandoned sites. The engineering geological hazards and risk analysis including assessing the vulnerability of people and facilities placed in the vicinities of the sites and valuation of elements at risk should also be considered.

The present work dealt with original data available from Chiodi *et al.* (1982), São Paulo State Government (1989), and Ferreira (2003), which were supplemented by limited fieldwork data for a total of 106 sites. The preliminary analysis of these data provides the following statistics:

- There were 33 mineral exploitation sites in 1982 (18 operational, 11 abandoned). In only five years (between 1982 and 1989), an increase of 53 mineral exploitation sites was observed (49 in residual soil), whilst between 1989 and 2003 about fifteen new sites were exploited;
- Mineral exploitation activity has constantly been reduced, from 22 sites in operation on 1981, to 18 in 1989, and just one in 2003 (due to a halt enforced by authorities). Fifteen sites where mining and /or quarrying operations stopped in the early 1980's were considered to have undergone natural recovery.
- The present-day environmental impacts and hazards closely resemble those of the previous studies. In both cases 53 to 62% of sites were reported to be subject to severe impacts, although in the previous studies the main impact was considered to be deforestation or removal of vegetation cover.
- 95 out of 106 sites identified in the current work, were visited and described at outcrop scale. Environmental degradation was considered to be significant in about 25 % of these sites, which gives evidence for the need for the implementation of measures to promote reclamation and/or redevelopment.

Characterization of environmental degradation

Limited fieldwork was undertaken for a rapid reconnaissance of 101 sites identified in previous studies. The central idea was to perform a pre-classification of sites and rank them in relation to geo-environmental problems and current land use situation, which in combination with socio-economic and political aspects (such as mining and environmental licensing status, land ownership, current legal actions etc) could justify the need for further detailed studies to support reclamation and/or regeneration (after-use) planning. The characterization procedure considered the following factors: (a) location, particularly distance in relation to the road network and main urban areas; (b) mineral exploitation status (active or not, semi-active); (c) vegetation cover (current type and/or degree of re-vegetation); (d) land stability; (e) scenic aspects and land uses in the vicinity; and (f) potential for mineral exploitation. A photographic record was made of the 95 sites visited (see examples at Figures 5, 6, 7, 8, 9, and 10) as well as proposals made for future use (or function). Of the 101 sites, six sites could not be accessed and five new areas have been identified and described.

It was observed that at a number of sites, where manual or mixed mining operations (mechanical and manual pull-out, with or without blasting) for ornamental stone and/or residual soil was reported, vegetation was recovering reasonably well in relation to neighbourhood vegetation thus reducing the visual impact of the sites. Similarly, in other sites where residual soil exploitation took place, re-vegetation has occurred naturally by opportunist herbaceous species, particularly Gleicheniaceae, with grasses, including *Paspalum spp*, *Panicum spp* e *Brachiaria spp*) and common weed species.

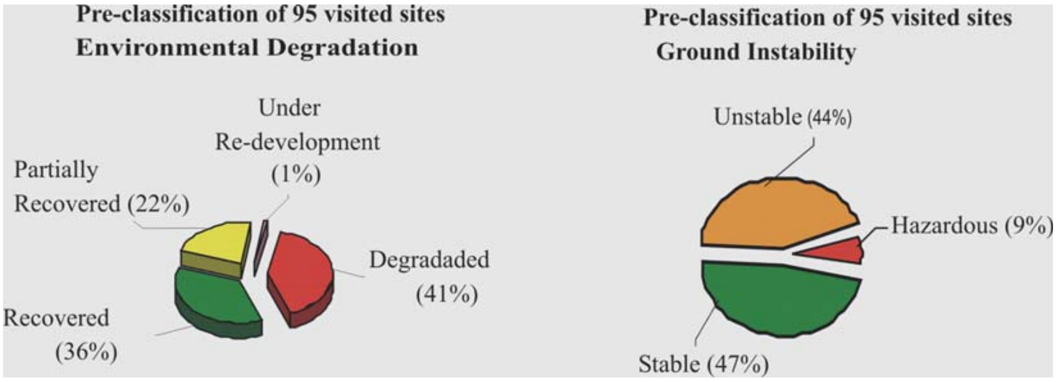

Figure 3. Pre-classification of sites with reference to environmental degradation and ground instability.

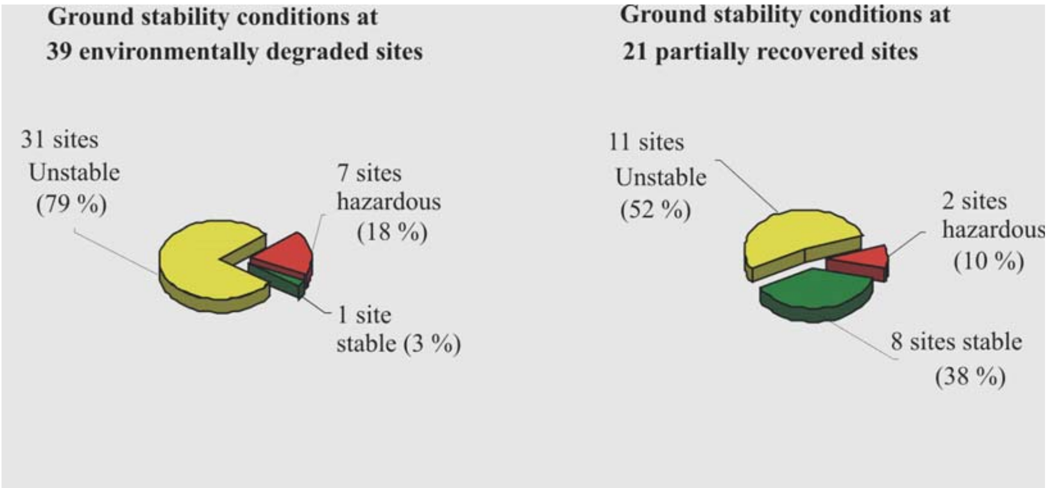

Figure 4. Pre-classification of environmentally degraded and partially recovered sites cross-referenced to ground instability.

The degree of environmental degradation (see Figure 3) was pre-classified as follows:

- 34 sites were considered to be recovered (Figure 10), in that they are reasonably stable in engineering geological terms, free of significant erosional or other geodynamic processes (e.g. soil piping, soil creep), covered at least by primary re-vegetation (as cited above), and reasonably integrated in scenic terms with surrounding environment and land uses;
- 21 sites were classified as being partially recovered (Figure 8), such that different conditions, geodynamic processes and magnitudes of ground instability were observed in combination with poor or no natural re-vegetation, thus also entailing some scenic deterioration in relation to the surroundings;
- One former residual soil ("saibro") exploitation site is being redeveloped as a municipal landfill facility for domestic refuse;
- 39 sites were pre-classified as being environmentally degraded (see Figures 5, 6, 7, and 9), in which geotechnical and engineering geological problems were present, including significant ground instability, mostly in combination with severe removal of vegetation and scenic deterioration. One of these sites is currently licensed (mining and environmental) and from which residual soil is being extracted (Figure 7). A further 10 sites were considered to be semi-active as illustrated in Figure 6 (mainly sporadic unlicensed operations), and 28 sites were considered to be completely abandoned and/or derelict, a number of them involved difficulties in identifying those liable for reclamation works (see Figures 5 and 9).

Comparing environmental degradation against ground instability aspects can derive additional interpretations:

- 44 sites with no evidence of instability were pre-classified as stable (Figure 3) in engineering geological terms. These correspond with the 34 sites considered recovered, 8 sites partially recovered (Figure 4), 1 site degraded (Figure 4), and 1 site being re-developed.
- 42 sites were pre-classified as unstable (Figure 3) in view of evidence of geodynamic processes including erosion, landsliding, mudflows, rockfalls, and also ponded water, flooding and silt-up due to high rates of run-off, and in most cases involving different ground conditions and magnitude of hazards. These included 31 sites considered to be environmentally degraded and 11 areas partially recovered (Figure 4).
- 9 sites were pre-classified as hazardous and of high risk areas (Figure 3) due to geodynamic instability processes, such as erosion, landsliding, rockfalls, and block tilting, in close proximity to informal housing

and/or urban infrastructure (roads, electricity distribution lines, buildings etc) as exemplified in Figures 6, 7, 8, and 9. These included either environmentally degraded sites (some semi-active) or partially recovered sites (Figure 4).

To facilitate an understanding of the regional geo-environmental setting, the municipality territory was divided into physiographic compartments. These are comprehensive terrain units comprising a reasonably homogeneous mix of rocks, topographic features or landforms, soils and/or unconsolidated deposits (see Fernandes da Silva *et al.*, 1997; Vedovello & Mattos, 1998; Vedovello, 2000; Cripps *et al.*, 2002). The sites visited are distributed throughout 21 different types of physiographic compartments (see Table 1), but they were most frequently associated with equigranular and coarse-grained pyroxene-bearing granite (charnokite), which forms moderate to steep hill slopes with convex tops. Secondarily, sites are associated with porphyritic biotite-granite, which underlie steep hill slopes with sharp aligned tops. The third type of site is associated with colluvial deposits with low-declivity ramps and terraces.

Exploitable residual soil profiles usually consists of predominantly clayey and sandy-clayey horizons up to 10 m thick, although in some cases significant thickness of saprolitic soils are also removed and used as aggregate. In a number of sites it was not possible to identify the thickness and the type (texture and mineral composition) of residual soil horizons as they have been totally removed and utilized. Due to the absence of soil materials and damage to soil structures, this has had serious implications for the natural recovery of vegetation. Frequently re-vegetation of degraded areas is by opportunist herbaceous species such as Gleicheniaceae and has led a number of authors to regard such plant formations as (phyto-) physiognomic units.

DISCUSSION

Throughout many years, exploitation of residual soil has been poorly planned and controlled in Brazil. The main reason for this is a lack of understanding by authorities and pertinent regulatory bodies that the material is a mineral deposit traded as aggregate. This led to tacit acceptance of a widespread "off the record" activity, the legacy of which is a number of environmentally degraded and derelict sites (Ferreira *et al.*, 2005). The 106 sites registered in the municipality of Ubatuba are a result of this and as such, poses significant challenges to engineers, quarry operators, planners and policy makers.

The whole scenario is a complex one involving several diverse areas that may hinder environmental recovery. Problems include inaccurate records of land ownership, lack of mining and environmental licensing of active operations, litigious processes that aim to define liabilities, and informal occupation and settlement by local populations at the sites. The occupation of sites in particular, usually exacerbates instability hazards and creates highly hazardous conditions whether or not mining operations recommence. The disused quarries are unsightly and pose a number of hazards, including: mass instability of steep faces, rockfalls from steep faces and spoil heaps, mudflows where soil becomes mobilised by high rainfall, ponded water that results in mosquitoes and drowning hazards, and flooding due to high rates of run-off.

On the other hand, there is a significant local demand for the aggregate product for civil construction and road maintenance the exploitation of which has the potential for causing serious environmental damage to nature reserve areas (State Park) that are supposed to be preserved in view of their importance to regional economic activities centred on tourism and leisure activities. There are also geotechnical aspects to be considered as the properties of the residual soils with respect to its use as fill and long-term performance of rock and soil slopes have not been investigated. Of particular importance are the effects of relatively small differences in soil composition, texture and moisture content on its properties.

Environmental degradation varies in magnitude and depends on local conditions. In most cases, degradation involves the removal of both superficial and residual soil horizons. The weathered rock (saprolite) has also been removed at a number of sites, all without planning of the mining operations or any form of care in relation to surrounding environments. Due to absence of soil and frequent damage to soil structure and chemistry these actions give little opportunity for either natural vegetation recovery or re-vegetation (with or without native species). Intrinsic terrain characteristics may also dictate natural ground susceptibility to geodynamic processes such as erosion and mass movements, which may be exacerbated by informal site occupation which also result in high to risk situations (see Figures 6, 8 and 9). In general, the magnitude of environmental degradation is directly related to a combination of damage to vegetation, removal of soil cover, and ground instability, which together result in scenic deterioration.

An approach that could be considered would be to allow exploitation from selected derelict sites where potential residual soil deposits have been identified. In fact, twelve sites have been preliminarily identified having reserves and should be further studied in more detail. These sites correspond with physiographic compartments (see Table 1) where thicknesses of soil weathering profiles were estimated to be greater than 5 meters (see also Figures 7 and 9).

A ranking scheme whose aim is to prioritize sites for socio-environmental regeneration should be devised and implemented. Such a scheme would need to include alternative strategies to rectify the damage caused by existing sites, while imposing strict conditions on the operation and post-mining reclamation of any new sites to ensure that mineral exploitation is compatible with mitigation and reduction of risk, and the after-use or redevelopment of sites. In most cases further detailed studies would be needed to indicate best practice models for reclamation. Sites owned by the Mayoralty itself are likely to be primarily used for practical implementations and demonstration of these. Other urban areas along the Atlantic coast and elsewhere in Brazil experience similar dereliction problems so it is useful to formulate a methodology for developing appropriate solutions to the problem.

Table 1. Characteristics of physiographic units (compartments) where residual soil and ornamental stone mineral exploitation sites have been identified.

UNIT CODE	Number of Sites	Physiographic Sector	Bedrock	Landform	Declivity (degrees)	Slope Profile	Fracturing	Soil and unconsolidated deposits	Thickness
LCR	7	Coastal Plain	Colluvional deposits, talus, and alluvional fans	Low declivity ramps situated at mid-slope and foothills	No data	No data	Very low fracturing	Sediments with sandy-silty-clayey matrix	No data
LMT	11	Coastal Plain	Equigranular to coarse-grained charnokites (green granites)	Isolated residual hill within shore strings and marine terraces	No data	No data	No data	No data	No data
LRC	17	Coastal Plain	Porphyritic biotite granites	Residual hills with convex tops	No data	No data	No data	No data	No data
SCR	5	Mountain Slope	Colluvional deposits, talus	Coluvional and talus ramps at foothills	No data	Rectilinear	Moderate fracturing	Sandy-clayey	No data
SGC1	2	Mountain Slope	Porphyritic biotite granites	Rolling hills – convex tops	No data	Convex	Moderate fracturing	Sandy	0 to 5 m
SGC3	3	Mountain Slope	Porphyritic biotite granites	Rolling hills – convex tops	15-30	Rectilinear	Moderate fracturing	Sandy	0 to 5 m
SGC4	2	Mountain Slope	Porphyritic biotite granites	Rolling hills – convex tops	15-30	Rectilinear	Moderate fracturing	Sandy	0 to 5 m
SGM1	2	Mountain Slope	Porphyritic biotite granites	Elongated hills – sharp tops	30-47	Convex	Moderate fracturing	Sandy	> 10 m
SGM4	1	Mountain Slope	Porphyritic biotite granites	Elongated hills – sharp tops	30-47	Concave	Moderate fracturing	Sandy	5 to 10 m
SGM5	7	Mountain Slope	Porphyritic biotite granites	Elongated hills – sharp tops	15-30	Concave	Moderate fracturing	Sandy	5 to 10 m
SHC2	7	Mountain Slope	Equigranular to coarse-grained charnokites (green granites)	Rolling hills – convex tops	30-47	Convex-Concave	Moderate fracturing	Clayey	5 to 10 m
SHC3	3	Mountain Slope	Equigranular to coarse-grained charnokites (green granites)	Rolling hills – convex tops	30-47	Convex-Concave	Moderate fracturing	Clayey	5 to 10 m
SHC5	17	Mountain Slope	Equigranular to coarse-grained charnokites (green granites)	Rolling hills – convex tops	15-30	Convex-Concave	Moderate fracturing	Clayey	5 to 10 m
SHC6	3	Mountain Slope	Equigranular to coarse-grained charnokites (green granites)	Rolling hills – convex tops	15-30	Convex-Concave	Moderate fracturing	Clayey	5 to 10 m
SHC7	5	Mountain Slope	Equigranular to coarse-grained charnokites (green granites)	Rolling hills – convex tops	15-30	Convex	Moderate fracturing	Clayey	> 10 m
SHC8	4	Mountain Slope	Equigranular to coarse-grained charnokites (green granites)	Rolling hills – convex tops	15-30	Concave	Moderate fracturing	Clayey	5 to 10 m
SHG1	2	Mountain Slope	Equigranular to coarse-grained charnokites (green granites)	Rugged hills – sharp tops	30-47	Convex	Highly fractured	Clayey	> 10 m
SHM4	6	Mountain Slope	Equigranular to coarse-grained charnokites (green granites)	Elongated hills – sharp tops	15-30	Rectilinear	Moderate fracturing	Clayey	0 to 5 m
SHM5	1	Mountain Slope	Equigranular to coarse-grained charnokites (green granites)	Elongated hills – sharp tops	15-30	Convex	Very low fracturing	Clayey	> 10 m
SHM7	2	Mountain Slope	Equigranular to coarse-grained charnokites (green granites)	Elongated hills – sharp tops	15-30	Concave	Very low fracturing	Clayey	5 to 10 m

Figure 5. Example of an abandoned environmentally degraded site. Note close proximity of housing.

Figure 6. Example of an environmentally degraded site. Semi-active mineral exploitation contributing to hazardous conditions due to potential instability.

Figure 7. Example of an environmentally degraded site. Active mineral exploitation of residual soil (licensed). Hazardous area due to declivity, ground instability and close proximity of housing areas.

Figure 8. Example of an abandoned, partially recovered site. Note hazardous area due to ground instability, close proximity of road, and potential for occupation by low income populations.

Figure 9. Example of unsightly and environmentally degraded site with potential for mineral exploitation of residual soil. Hazardous area due to declivity, ground instability (note detached blocks of rock), and informal occupation by low income populations

Figure 10. Example of recovered site. Note re-vegetation by grass and reduction of scenic deterioration

CONCLUSIONS

Between the 1960's and late 1980's intensive exploitation without appropriate planning and control, of residual soil and ornamental stone for civil construction took place in the municipality of Ubatuba. State and local authorities managed to stop unlicensed exploitation of this material by the early 1990´s but for a number of reasons land reclamation has not been undertaken.

The present study identified 106 sites, from which approximately 60 are considered to suffer from some kind of environmental degradation related to previous mining and/or quarrying operations. These sites cause scenic deterioration of the local landscape, which is vital for tourism. The sites also pose risks to the local population and urban infrastructure, which also discourages investment and economic activity in the municipality. Ninety-five sites were visited and studied in some detail, which allowed pre-classification of the sites into four main categories according to the hazard posed, need for reclamation, availability of resource for exploitation and opportunities for post-reclamation land-uses. In absolute figures sites were pre-classified as follows: a) recovered sites (34 sites); b) partially recovered sites (21 sites); c) degraded sites (39 sites); and d) under re-development sites (1 site). Ground instability problems have been observed at 51 sites, nine of which were pre-classified as hazardous due to the presence of active erosion, landsliding, rock slabing, rockfalls, and block tilting.

Hazard reduction and reclamation of many sites is urgently required, particularly in view of the close proximity of the population and State Park. There are a number of cases of dwellings being constructed in hazardous locations within unsightly quarries and action is required to assess the stability condition of quarry faces and spoil heaps, with risk assessments of failure and appropriate action to reduce risks. Some faces in excess of 50 m high show signs of instability, thus stabilisation, back filling or regrading are required. The latter would necessitate extension of the area of the quarry, and problematic land ownership and planning issues would need to be addressed.

The formulation of strategies and policies for the local and regional mining sector is essential to address the problems and should require active involvement of municipal authorities. Such strategies should investigate ways of directing mineral exploitation and production of aggregates for construction to those areas already degraded and in need of reclamation. The planning process should take into account potential future uses for reclaimed sites and risk reduction.

Acknowledgements: The authors would like to thank the work team, especially Dr. Ricardo Vedovello and Mrs. Lidia K. Tominaga for their contributions to fieldwork and data analysis, and to FAPESP (São Paulo State Research Support Foundation) – Public Policies Research Program for sponsoring the current study (Grant nr. 03/07182-5).

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