ADDRESSING SOCIO-ENVIRONMENTAL CONFLICTS IN CASES OF COAL MINE SUBSIDENCE IN BRAZIL AND THE USA

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Introduction

Mineral assets play a significant role in the history of humanity. According to Nunes (2006), it is almost inconceivable that the quality of human life, of production and consumption, can be guaranteed and improved without the exploration of mineral resources and, in this way, sustainable development is also heavily dependent on mining.

Nevertheless, the exploration of mineral resources can lead to socio-environmental impacts and conflicts, which result from animosities, associated either to converging or diverging interests concerning the exploration of natural assets, such as coal mining. They can also be due to present-day environmental problems which are the result of past resource exploration, such as the exploration of the coal basin in Santa Catarina. Sánchez and Croal (2012, p. 51) discuss the use of impact assessment tools for promoting sustainable development. They argue that “conflicts of any type should no longer be accepted as part of the development and decision-making process”.

From a global point of view, Santa Catarina is the second largest coal producing state in Brazil (DNPM - National Department of Mineral Production, 2010), whereas Illinois is in ninth position among coal producing states in the USA (BAUER, 2008).

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these two states, environmental degradation due to coal exploration is very significant, affecting the environment and quality of life in the region. For a number of decades, studies have been conducted with a view to understanding and mapping degradation as a result of inactive coal mines, in particular in Illinois. Many of these studies relate to the impact of subsidence in underground mines. They provide relevant information to implement land use and occupation planning actions and for mitigating the impact of environmental damage and related socio-environmental conflicts.

A number of authors have studied environmental conflicts. Pasquino; Bobbio; Matteucci (1986) argue that conflicts are a form of interaction between individuals, groups, organizations and other collectivities which involve struggles associated to the access and distribution of scarce resources. In order to understand them it is important to analyze the agents involved in these phenomena, as well as the physical and institutional environments where they take place. Carvalho; Scotto (1995) state that socio-environmental conflicts revolve around nature, often giving rise to confrontations between private interests and the common good. Pasquino; Bobbio; Matteucci (1986) and Carvalho; Scotto (1995) believe that socio-environmental conflicts are characterized by struggles within the same physical space or spaces in close proximity to where mining (in particular exploration) and other land use and occupation activities occur.

There has been little research relating to subsidence of underground mines and its effects in Brazil. The main published works on this subject are technical reports from the DNPM – [National Department of Mineral Production] and a few dissertations at Master’s level. Conflicts associated to the subsidence of underground mines in Brazil occur mainly in the state of Santa Catarina, although there have been some occurrences related to zinc mining in Minas Gerais (SEVÁ, 2011). Coulon (1990) describes an emblematic case of the subsidence of an underground coal mine in Criciúma, Santa Catarina, which affected a social housing complex.

In the United States, with regard to legal protection associated to conflicts due to subsidence, federal mining legislation sets out specific regulations for the consequences of subsidence - the Surface Mining Control and Reclamation Act (SMCRA), in force since 1977. The implementation of this federal law in Illinois resulted in the Abandoned Mine Lands Reclamation Council which receives federal government funds for the recovery of inactive mining areas. This fund promotes the adoption of measures to reduce risks affecting the safety and protection of people’s lives in cases of subsidence of inactive mines. The states of Pennsylvania, Illinois, Kentucky, West Virginia, Ohio and Colorado have insurance subsidence programmes (GRAY, 1990).

By contrast, the Brazilian legislation applicable to cases of subsidence is vague and only requires that the area affected by coal mining is recovered for future use after mining has ceased (SÁNCHEZ, 1995). According to Coulon (1995), most of the problems associated to the subsidence of coal mines have been settled in court within the framework of civil and criminal liability. Baccin's recent research (2011) confirms this assertion, noting that in cases where no agreement has been reached with a mining company, compensation for damages caused by subsidence is usually pursued through the courts. Subsidence cases which resulted in damage to third party properties in
the Santa Catarina municipalities of Treviso, Siderópolis, Forquilhinha, Criciúma, Urussanga and Lauro Müller are currently under consideration in the Federal Courts (BACCIN, 2011).

The Brazilian legal instruments which regulate the winding up of mining activities are generally broad and address the issue of subsidence of mines in generic terms. Sánchez (2011) highlights that in current discussions about the mineral sector, the issue of mine closures requires more in-depth consideration due to the legacy of environmental liabilities frequently associated to mining. A notable example is the case of abandoned mines and degraded areas in Santa Catarina’s coal basin.

This article addresses socio-environmental conflicts caused by subsidence which affect homes, rural properties and communities in the state of Santa Catarina, in particular in the municipality of Criciúma, Brazil and Illinois in the USA.

The aim of this study is to analyze disputes related to the subsidence of inactive coal mines explored via the “room and pillar” method, both in Illinois and in Santa Catarina. We seek to identify relevant lessons (lessons learned) from the American case that can be used as reference for environmental management in the areas affected by this phenomenon in Santa Catarina.

We understand “lessons learned” to be knowledge obtained through practical experience which merits attention and can be re-applied in situations similar to the ones for which they were originally developed (RUIZ, 1996; DZIEGIELEWSKI; GARBHARRAN; LANGOWSKI JUNIOR, 1993).

Methodological procedures

This article presents a qualitative and exploratory study developed in two stages: the first involves a review of the lessons about subsidence learned in Illinois, while in the second statements are validated and reviewed by Brazilian coalmining specialists.

a) Reviewing the lessons learned in Illinois

A set of statements from preliminary lessons were drawn up after a careful review of the literature and publicly available documents at the Illinois Department of Natural Resources, Office of Mines and Minerals (Benton, IL) and conversations with the Department’s mining regulators and inspectors.

Subsequently, the Policy Delphi method (an offshoot of the traditional Delphi) was used so that lessons were assessed by coalmining industry experts or professionals who had been either directly or indirectly involved in the implementation of the Surface Mining Control and Reclamation Act (SMCRA), a federal law approved in 1977, in Illinois.

The semi-structured questionnaire contained twelve lessons, expounding statements together with their justifications (which were drawn up from the literature review and conversations with mining regulators and inspectors), as well as questions on the validity and relevance of these lessons for the various interest groups in Illinois,
as well as for other coalmining countries such as Brazil. These lessons related to the following subject matters: a) the safety of underground mines; b) the economic benefits of underground mines with high extraction rates; c) subsidence prevention; d) the compatibility of planned subsidence with other land and occupation uses; e) the suitability and effectiveness of regulations on subsidence; f) communication as a key element for the success of implementing subsidence regulation; g) dissemination of information on subsidence to the population; h) agreements in disputes involving damages due to subsidence; i) agreements to reduce disputes of a regulatory nature; j) the intervention of regulatory agencies to ensure the mitigation of subsidence impacts; and k) the role of environmental groups in implementing subsidence regulation.

During the first round, 214 questionnaires were sent to potential participants with 87 replies returned. Four questions (two on validity and two on relevance) were answered per lesson. In addition, most respondents made comments and suggestions with a view to improving the statements of the lessons.

The statements referring to each lesson were partially or totally reformulated, based on the comments received. This resulted in three new lessons. Thus, during the second stage, participants assessed a total of fifteen lessons. The subject-matter of these three new lessons related to a) environmental advantages of planned subsidence; b) the reduction of exploration tax to decrease or prevent subsidence damage; and c) the restoration of soil productivity in areas affected by subsidence.

This second questionnaire was sent to the 87 respondents from the first round for their reaction and revision, resulting in a total of 51 responses.

Taking into account this new assessment round of fifteen lessons, all suggestions were accepted.

Out of the fifteen lessons with adapted statements, only three were selected, based on their validity and relevance for Brazil. Thus, the following lessons were to be confirmed and updated by Brazilian coalmining experts: 1) The registration and mapping of inactive mining areas in order to establish the areas at risk of subsidence; 2) Dissemination of information on subsidence and the responsibilities involved as a way of preventing undesirable impacts and related socio-environmental conflicts; 3) Establishing subsidence insurance in areas at risk of subsidence.

b) Confirming whether the lessons learned are important for the Santa Catarina coal basin

Assessing the importance of the lessons took place in 1995 and 2013. The aim was to identify and analyze not only the validity of US lessons for Brazil, but also the potential evolution of the approach to these conflicts during this timeframe.


The questionnaires sent to Brazilian specialists contained three questions on the three lessons which had been previously defined as relevant to the Brazilian case:
1) Do you think this lesson is (may be) important for Santa Catarina? Please expand.
2) Based on your practical experience and/or knowledge of coal mining and its impacts in the south of Brazil, how would you reformulate this lesson so that it can be applied to mitigate subsidence problems in Santa Catarina? Please expand.
3) Do you think that the study being conducted in Illinois could be useful for the future drafting of legislation, regulations and technical standards regarding the subsidence in mines in Brazil? Please expand.

In 2013, after updating the literature review on conflicts associated to the subsidence of coal mines in the south of Brazil, it was observed that only two of the participants of the 1995 study were still active in the field. Therefore, face-to-face interviews were carried out with these two coal specialists (MENEZES, 2013; VALIATI, 2013). Interviews encompassed socio-environmental impacts and conflicts related to subsidence and provided for both validation and updating of the lessons for Santa Catarina.

**Underground coal mining in Santa Catarina and Illinois: understanding subsidence issues**

The coal deposits in Santa Catarina have been known about since 1827, when they were first explored by English companies (WHITE, 2008). A new cycle of coal exploration started in Santa Catarina in 1913. The first coal deposits were mined in Criciúma, generating economic development, employment and attracting investment. This cycle reached its peak between the 1940s and 1970s (VOLPATO, 1982). Currently, Criciúma is known as “Brazil's coal capital” (Figure 1).

In the Criciúma region, the coal deposit strata have an average depth of between 35 and 45 metres. However, it surfaces (subsurface between 1 and 10 metres) in a number of localities. This means that open-air mining has always been more predominant than underground mining (COULON, 1990).

In contrast to other countries with a coal mining tradition, underground mines are shallow or of medium-depth. Room and pillar is the method employed (Figure 2), where digging can be either done manually, be semi-mechanized or mechanized. According to Coulon (1990), room and pillar involves opening access and underground galleries, delimiting the areas from which coal is extracted.

Room and pillar mining occurs in two stages. First, miners move forward, putting up the pillars which sustain the roof of the chamber. When the end of the panel is reached, they start to retreat, removing the material from the pillars (CHAVES, 2013).

Subsidence may occur during the coal mining process. Subsidence is defined as “[...] the deformation or displacement in an essentially vertical descending direction, which manifests itself as a lowering of the ground” (INFANTI JUNIOR; FORNASARI FILHO, 1998). After mining terminates, new subsidence (slow dipping event) or collapses (rapid events, a type of subsidence in which the land moves quickly, according
According to Zingano; Koppe; Costa (2004), collapses can be classified as either violent or non-violent in accordance to the number of pillars involved and the speed of the event. In the two years prior to 2002, there were four large collapses which were responsible for the caving in of hundreds of pillars (approximately 700) in Criciúma, classified as a violent collapse and affecting 100 pillars in 3 hours (ZINGANO; KOPPE; COSTA, 2004). Problems related to pillar size are responsible for the majority of collapses in the Criciúma coal mines. However, there are other reasons for this phenomenon such as the geological characteristics of the mineral deposits, as highlighted by Zingano; Koppe; Costa (2004).

During the 1970s, the DNPM authorized coal companies to partially remove pillars (subsequent to the mining of the panels) in order to increase the productivity of underground mines (SCOTTO, 2011). This action had a direct impact on the number

**Figure 1**: Schematic drawing (no scale) of part of the Santa Catarina coal basin, highlighting Criciúma

Source: Centro Acadêmico de Letras, Extremo Sul Catarinense University (2013)
of subsidence cases, especially in relation to the size of the areas affected by collapse, compromising the security of adjacent buildings and leading to a loss in farm land in rural areas (BRUM VAZ, 2003). As Valiati (2013; 1995) highlights, this resulted in the lowering of the water table with a consequent reduction in the flow or the disappearance of surface water. Furthermore, there were damages to construction works. These incidents led to a growing number of conflicts between the population and mining companies, involving public civil actions which resulted in the suspension of the permit granted by the DNPM,
under the Collor government in 1990. According to Almeida (1995), once the removal of the pillars was prohibited, the number of law suits significantly reduced. However, there were some cases in which pillars were not removed and where the rotting of the system for shoring up access galleries led to subsidence, including some incidences of collapse.

According to Milioli (1993), coal mine subsidence within the urban and surrounding areas of Criciúma affects both homes and agriculture. The most affected are the people living in the periphery, since they are generally less informed and more likely to be unfairly treated during negotiations in the case of damages to their buildings.

It is important to stress that from the 1980s, legal requirements regarding the exploration of minerals were tightened. This was the result of environmental legislation implemented in Brazil, namely, the National Environmental Policy - NEP - Federal Legislation n. 6.938/81 (BRASIL, 1981b).

The state of Illinois has extensive and high quality coal reserves. It is first in terms of reserves and ninth in terms of production in the USA, according to the Illinois Department of Mines and Minerals (1990). The 20th century saw the large-scale occupation of the American Mid-West which resulted in an increase in underground coalmining, the most important source of energy at the time. Due to the growth of underground mining employing the limited technical knowledge available at the time, there was an increase in subsidence cases, resulting in the first legal disputes between mining companies and the local population. The room and pillar method was introduced in Illinois around 1910 (HUNT, 1978). The greatest number of subsidence cases involve inactive mines (in operation until 1930), caused by the extraction of between 40% and 80% of available coal.

The legal framework applicable to coal exploration in Santa Catarina and Illinois: mining law, land occupation and responsibilities

In order to understand how socio-environmental conflicts associated to coal exploration came about in these two localities, it is important to analyze how the concept of land and other specificities of mining laws regarding ownership and duties are understood.

In relation to mining law, in the American mining states, the applicant (the mining or private company) requests the use of the mineral-rich land by filling in and submitting a mining permit form to the relevant authorities. In Brazil, mining law is regulated by the chronological priority of the request submitted to the DNPM, once the criteria set out in the Mining Code and correlated legislation have been complied with (BRASIL, 1981a). Mining law, specifically in the case of coal has been consolidated since 1981, since the Mining Concession Decree was established. Concessions depend on environmental licensing.

With regard to land ownership, according to the Brazilian Mining Code (BRASIL, 1981a), for mining purposes (extraction and use), mineral ores are considered to be underground resources, even in cases when there may be a physical confusion between underground (subsoil) and ground (soil). This is the case, for example, with sand, gravel and clay which are frequently found on the surface, but in terms of economic exploration and from a legal point of view, they are considered to be underground resources. In
Illinois, a state with a strong agricultural tradition, surface rights are generally given to smallholders, where they have the right to build their homes. According to McMartin, Whetzel and Myers (1981), in the USA, those with land property rights do not necessarily own the right to the mineral ores (including coal) in the subsoil. In some areas there may be a number of layers, each belonging to different owners. Mining rights can be acquired or sold separately from those of the surface, and transactions of this type have been common throughout American history. It is worth noting that in Brazil, applicants also do not have to own the land, but owners must give permission for the exploration of the minerals that lie in the subsoil of the land belonging to them. The underlying logic is that the Brazilian Federative Union owns the subsoil and grants authorization for the exploration of mineral assets.

The separation between land rights and subsoil rights is important because of its implications for subsidence cases and in establishing responsibilities. According to Illinois Case Law, coal mining companies are liable for damages caused to the land and structures found on the surface. This legislation is the basis for establishing the liability rule which underpins subsidence regulations. The liability rule states that: “the holder of mining rights gives an undertaking to the owner or occupier of the land to leave a certain amount of mineral intact (not mined) so as to protect the natural state of the surface land”.

According to the Mining Code (BRASIL, 1981a) and to Brazilian environmental legislation (established in the law itself or via the National Environmental Policy, NEP, Law n. 6.938/81), when a company holds the mineral rights to an area, it is liable for all damages directly and indirectly caused by mining (mining, processing and transporting of minerals) to third parties, including to the occupiers of surface land above mining areas. In all situations, the party who causes the damage is liable, even if liability needs to be enforced through legal action (VALIATI, 2013). This “rule” is valid even when a company acquires the mining rights from someone who has environmental liability (“bought an asset, gained a liability”). Liability also applies to environmental externalities (environmental impacts, socio-environmental conflicts) which may have been caused by the extraction activities of any other company that may be jointly operating in a particular locality. From the legal point of view, a company holding mineral rights can be made liable and penalized by the competent authorities for subsidence damages affecting the land, houses and urban structures in districts situated above a mine, for as long as it exists.

**Socio-environmental conflicts resulting from subsidence in coalmining areas**

According to Scotto (2011), in recent years there have been a growing number of social conflicts involving mining. With regard to underground coal mines, Margulis (1985) argues that the main disputes relate to the impacts of the subsidence of old mines, as well as to pollution generated within the mines themselves (labour conflicts).

The main disputes involving mining and other land use and occupation activities in the coalmining regions of Santa Catarina and Illinois are described here.
a) Mining versus Urbanization

Generally speaking, the main disputes involving different types of land use and occupation are aggravated in the periphery of large cities where there are a considerable amount of irregular properties and a population which experiences greater disadvantage, living in self-built homes and in social housing with precarious infrastructure.

In recent years there have been many cases of subsidence due to the expansion of the number of plots and buildings over inactive mines in the districts of Criciúma and Lauro Muller. This gives rise to potential socio-environmental conflicts. In Criciúma, the districts of Pio Correa, Santa Catarina, Maria Céu and São Cristovão were the most affected (VALIATI, 1995). The construction of buildings and communities on sites above areas which had previously been mined results in the overload of surface areas which, depending on the state of the ceilings in the galleries and the rocks both above and below the mined chambers, may trigger collapse.

One of the most serious cases recorded by Coulon (1990) resulted in damage to 11 brick houses out of a total of 420, in the Housing Co-operative Complex Criciúma III (COHAB), built over an underground mine which used the room and pillar method. Coulon describes the collapse of the roof of a coal extraction room which resulted in subsidence, described as circular-shaped with a diameter of 60m and a 1.5m sag in its centre. Scotto (2011) states that after this subsidence in February 1983, investigations revealed that the DNPM had no records of the mine’s layout or information on retreat (posterior pillar removal). Ramos (1995) stated that considering the mine was granted a concession in the 1930s and the housing complex was built in the 1980s, the question arises of how to conciliate these interests?

It is important to note that in 1980 there were no legal requirements to conduct Environmental Impact Assessments for prospective ventures, in this case the building of the housing complex. However, this also applied to a large array of mining and engineering works. This was later set out in the NEP (legislation n. 6.938/81) and linked to environmental licensing granted by Decree n 88.351/83 (later substituted by Decree n. 99.274/90); the enforcement of this instrument came into force via the Conama [National Environmental Commission] Resolution n. 001/86.

The building of the COHAB housing complex above a mining area is a typical example, which used to occur before the NEP, of the absence of planning before urban occupation. In addition, there is a lack of specific legislation regarding plans for occupying areas affected by mining which are subject to subsidence. Even taking into account the lack of specific legal framework, incidences could be reduced if the responsible authorities complied with the precepts set out in article 3, Lehmann Law, n. 6.766, from 19/11/1979 (amended by law n. 9.785 from 29/01/1999, which did not modify article 3), regulating the partitioning of land and requiring four geological reports to be submitted in order to approve land parcelling or construction projects (BRASIL, 1979).

Cases of subsidence affecting surface properties or structures in Illinois have been described by a number of authors (MEIER; GIBSON, 2002; TREWORGY; HINDMAN, 1991; DARMODY et al., 1989; GUITHER, 1986; GUITHER; HINES; BAUER, 1985;
DEMARIS; BAUER, 1983; HUNT, 1980; HUNT, 1978). Material damages reported involve claims relating to different types of urban facilities such as schools, roads, streets, hospitals, airports, parks, lakes, sewage networks, and water supply and electricity cable networks.

The most complex cases involving the subsidence of mines in Illinois related to inactive mines (pre-dating the implementation of SMCRA) and mining companies which no longer existed or which had transferred their mining rights to one or more companies. In general, in situations where there had been a transferral of mining rights from one mining company to another, court cases dragged on for years until a judicial decision on these cases was reached.

b) Mining versus Rural Areas

In the state of Santa Catarina there are very few cases relating to the subsidence of inactive coal mines affecting rural areas. This is most likely due to localized effects, making it difficult to assess the causes of these subsidence cases which are frequently on a small scale and irregular.

Subsidence cases can be divided into two types: pit and sag. According to Bauer (2006), pit subsidence (Figure 3) varies in size: between 1.8m and 2.5m in depth and 0.5m and 12m in diameter. It seems to be most common in the rural areas of Santa Catarina state. Sag subsidence (Figure 4) forms a slight depression over a large area, which sometimes can be the size of a chamber and may vary between tens to hundreds of meters in depth and length. It generally occurs over areas which had been previously mined and where pillars disintegrated over many years or collapsed quickly (BAUER, 2006). Coulon (1990) described a case of this type of subsidence which occurred in 1988.

Studies related to the impacts of the subsidence of inactive mines in the central agricultural region of Illinois are discussed by Guither, Hines and Bauer (1985). These authors drew up an inventory of areas which had been previously mined and assessed the extent of subsidence above the underground mines and the economic impact to land owners, and suggested alternative policies to address this issue. There are no references to a similar inventory in the coal-producing region in the south of Brazil (VALIATI, 2013). However, Ramos (1995) stated that a few smallholders in the coal region of Santa Catarina do carry out agricultural inventories prior to the start of mining operations below their properties. This is due to the fact that compensation for surface damages, prior to 1990 (when the removal of pillars was permitted), was based on technical reports produced by the DNPM.

Almeida (1995) claimed that there is a reduction in soil humidity in areas affected by subsidence, leading farmers to allege a loss of productivity. Menezes (2013) describes his participation as an expert in a public civil proceeding brought by nine families in the municipality of Urussanga who managed to prove that the mining company was liable for the drying out of water sources and for damages to their properties.
Figure 3: Profile representation of a pit subsidence event, showing the surface effects of the collapse of rock strata above a layer of mined coal

Source: Modified from Bauer, Trent and Dumontelle (1993)
Addressing socio-environmental conflicts in cases of coal mine subsidence in Brazil and the USA

Westman (1985) highlights the need for anticipating and mediating socio-environmental conflicts as an instrument for the preventive management of impacts, damages and environmental liabilities. He stressed the following possible approaches toward conflict resolution: (i) an agreement between the parties; (ii) the drafting and implementation of policies (for example, mining zoning and master plans); and (iii) judicial decisions (arbitration).

In Brazil, the NEP (law n. 6.938/81) and a number of other laws set out that those responsible for a particular initiative are liable and responsible for the recovery of damages, provided there is proof of causal link (strict liability). Thus, the requirements for the exploration of natural resources, including mining, became considerably more rigorous with the implementation of the Brazilian environmental legal framework. In Paragraph 2, Article 225, the Brazilian 1988 Federal Constitution - which postdates the NEP - establishes the obligation to recover degraded environments in recognition of the impacts, degradation and environmental disputes caused by mining.

According to Sánchez (1995), the existing legislation which can be applied to cases of subsidence is vague and requires that the mining company recovers the area for some

Figure 4: Block diagram showing how cases of sag subsidence occur due to the collapse of the strata above the mined coal chamber and the effects of their impact on the surface

Source: Bauer, Trent and Dumontelle (1993)
other productive use. However, it does not specify the criteria for recovery. It is worth
stressing that the Brazilian legislation, via Federal Decree n. 97.632/89, establishes the
recovery of areas degraded by mining in a document entitled Plan for the Recovery of
Degraded Areas [PRAD]. PRAD must take into account the socio-economic impacts of
mine closures and the future rehabilitation of previously mined areas (SÁNCHEZ, 2011).
New mining ventures must submit a PRAD, together with an Environmental Impact Study
(also set out in the NEP). That is, these obligations must be complied with in projects
for opening new mines, as well as mines in operation since this decree came into force.

There is no specific regulation regarding the subsidence of mines in Brazil, and
therefore there are no legal instruments which regulate consequent disputes. Ramos
(1995) highlights the need for technical regulation and standards on subsidence in Brazil
in order to reduce the number of disputes between mining companies and the population
occupying the surface. He argues that specific legislation on this subject would regulate
the rights and duties of the parties involved.

However, in Brazil, subsidence falls under environmental damages, making respon-
sible agents liable to legal proceedings to ensure the recovery of degraded areas. Most
conflicts associated to mine subsidence in Santa Catarina and Illinois involve court cases
and are usually resolved within a legal setting which is the result of a lack of consensus
between the parties regarding both the recovery of damages caused and amounts of
compensation.

According to Braga Neto (2011), in recent years there has been a tendency in
Brazil to involve the public authorities responsible for the oversight and preservation of
the environment in order to arrive at a negotiated solution. Bodies such as the Federal
and State Public Prosecutor’s Office, as well as state and municipal environmental depart-
ments, have played a significant role in prioritizing dialogue with regard to environmental
issues, based on co-operation. The main objective is to arrive at decisions (for example,
Conduct Adjustment Agreements [TAC]) which can be effectively complied with because
they can be perceived as being in the real interest of the parties directly involved or of
other stakeholders. These solutions must fall within the requirements stipulated by law
and must be in line with the aim of preserving the environment.

In the mining states of the USA, the Abandoned Mine Lands Reclamation Council
receives resources from the federal government from a fund for recovering areas damaged
by mining activities. This fund is made up of US$ 0.135 per tonne of resources explored
in underground mines and US$ 0.315 per tonne of resources explored open pit mines.
The aim of the fund is to provide health and safety and welfare protection, as well as to
protect the properties at risk of being affected by the impact of inactive mines, including
subsidence (US CONGRESS, 2013; MEIER; GIBSON, 2004).

With regard to finding solutions for conflicts as advocated by Westman (1985), it
can be observed that in Santa Catarina the approaches used are limited to arbitration and
some agreements between the parties. On the other hand, in Illinois, despite the adoption
of these practices, a clear interventionist approach is observed on the part of the State,
through the drafting of legal instruments which allow for palliative (or corrective) actions
in favour of the parties affected by conflicts and through a specific insurance scheme.
Addressing socio-environmental conflicts in cases of coal mine subsidence in Brazil and the USA

It is important to highlight that, within a context of socio-environmental damages and conflicts, the State may employ these planning instruments as preventive measures in areas at risk which have not yet been affected by these processes. Mining zoning and municipal master plans which take into account the specific factors of the local physical environment are examples of the government’s proactive approach in order to reduce these conflicts.

Analysis and discussion

The factors underpinning socio-environmental conflicts involving underground coal mines are linked to the separation of surface land ownership and the use of the subsoil for the purposes of economic exploration. In cases of subsidence there is an aggravating factor which relates to the lapse between the time mines were in operation and incidences of subsidence, which may actually be a considerable number of years. Therefore, when subsidence occurs, the legal framework may be different from when the mine was in operation, a situation that can result in legal disputes. This time lag may also impact on liability for damages caused on the surface. If, for example, the mining companies responsible for previous operations are still in existence or even if mining rights (mining permits) are still in force (even if they have been transferred to other companies), it may be possible to assign responsibility for subsidence damages incurred and disputes can be resolved. However, if companies close or mining rights expire, it is no longer possible to assign responsibility to damages caused and, in theory, it is the surface area occupier who must bear the costs. Nevertheless, according to Valiati (2013), in Santa Catarina civil proceedings are being executed at federal level related to environmental damages due to coal mining, caused by companies which no longer exist, and for which the Federal government may be liable.

Results: lessons learned in Illinois relevant for Santa Catarina

Here we present the statements and justifications related to the three lessons learned and which were validated and re-validated as important for the coal basin of Santa Catarina.

1) Mapping and registering inactive coal mining areas is essential for the zoning of areas at risk of subsidence

Bauer (2006) highlights that in Illinois, in order to comply with state legislation, mining companies must provide technical information (reports and maps) about mining activities to the State’s Mining Inspector and the Illinois Department of Natural Resources, Office of Mines and Minerals, as well as to the Office of the County Clerk. According to him, the Illinois State Geological Survey stores all the maps of inactive underground coal mines. These technical resources have stimulated the demarcation of the spatial boundaries of areas which had previously been mined. He estimates that there are 2,600 maps for approximately 5,500 underground mines in the state.
Original copies of the maps can contain important information about the mines such as location, size of pillars and surface facilities. These maps enable the identification of the type of mining conducted and relate it to existing surface structures (BAUER, 2006).

Meier and Gibson (2004) highlight that the Illinois Department of Natural Resources is continuously updating a geo-referenced database which combines mine maps, on a detailed scale, with surface maps for the entire state of Illinois. They claim that these maps come together with information sheets describing the history of the mines which include information such as the period of production, and changes in ownership of mines and operating mining companies. The information is useful for government authorities, private companies and society at large, both for land use and occupation planning in areas where mining occurred and for the technical substantiation of claims in cases of subsidence. This information needs to be widely disseminated and easy to access and understand, given that the best way of preventing these types of problems is to avoid the implementation of infrastructure above areas which may be at risk where mining had previously occurred and its surroundings.

Menezes (2013) stresses that knowledge of the subsurface conditions of the Santa Catarina coal basin is crucial, adding that this is the only way to produce information accessible to the public, estate agents, planning departments, legislators and the judiciary.

Thus, using the procedures adopted in Illinois as reference, together with the results of other research, it could be said that similar mapping of the coal region in the South of Brazil could be conducted by the Mineral Resources Research Enterprise [CPRM], as part of its responsibilities as a Brazilian Geological Service. It could produce maps of areas at risk of subsidence, based on individual maps of inactive mines together with information available on inactive and current mines, with the support of potential partners such as the DNPM, as well as the state and municipal bodies in the coal region.

Whenever possible, maps of underground mines should be complemented with information acquired through indirect research such as geophysical surveys (in particular those employing radar or electric technology), suitable for subsurface void detection, so as to improve the quality of the information available. Valiati (2013), in agreement with Zingano, Koppe and Costa (2004), argues that the depth of mines and consequently, land coverage and structural data (the spatial orientation of mining chambers, which are fundamental for assessing the stability of land) is important information that should also be considered. Valiati (2013) stresses that in specific situations direct investigations (surveys) should be conducted in order to obtain precise information on the location and depth of subsurface voids.

It is important to note that from the 1980s onwards, an agreement between Brazil and Germany meant that the DNPM started to request that mining companies provide a Mining Closure Plan which takes into account the state of the subsurface and contour maps of the structures surrounding the deposits, as well as coverage isomaps of depleted reserves. The DNPM has an archive of maps in a scale 1:20,000 which is regularly updated. These only map the areas which had been previously explored for coal in Santa Catarina (VALIATI, 2013). According to Valiati (2013), these maps do not contain data on subsidence. The DNPM only records cases of subsidence when parties occupying surface areas
make a complaint. It could be said, therefore, that no systematic geological or geophysical operations have been conducted to date in the coal basin of Santa Catarina, with a view to recording and providing information on the areas potentially at risk from subsidence. Valiati (2013) further states that a civil action instigated by the Public Prosecutor’s Office gave rise to an initiative, resulting in an inventory containing information about cases of subsidence due to coal mines. This can be considered as the most complete record of subsidence cases in the Santa Catarina region.

The mapping of depleted mines, together with the mapping of current surface and subsurface land use and occupation (buried infrastructure) could improve spatial information which would subsequently facilitate the risk zoning of mining areas. This is absolutely essential for an effective spatial planning of municipalities where there are areas exhibiting these characteristics. Baccin (2011) highlights the need for a register of inactive coal mines in Criciúma and for setting up a legal instrument, at municipal level, which would curb urban expansion in areas with a potential risk of subsidence. He further adds that the use of technical expertise can substantiate legal procedures when reaching decisions regarding the mitigation of damages caused to third parties due to mining.

2) Disseminating information on subsidence associated to mines and related responsibilities can contribute to preventing undesirable impacts and related socio-environmental conflicts

The literature review on topics relating to this lesson from Illinois points to the existence of a considerable amount of educational material, such as information sheets and manuals containing information in simple language and illustrations (photographs and schematic representations), concerning subsidence due to coal mines and its effect on homes (MEIER; GIBSON, 2004; BAUER et al., 1995; BAUER; TRENT; DUMONTELLE, 1993; DUMONTELLE et al., 1981), rural properties and drainage systems (BAUER, 2006; ILLINOIS DEPARTMENT OF NATURAL RESOURCES, 1993; ILLINOIS STATE GEOLOGICAL SURVEY, 1988).

According to Meier; Gibson (2004), damages due to subsidence tend to occur suddenly, with serious consequences for surface occupiers given that they frequently result in the rupture of water and gas supply pipes, as well as broken roads and buildings. Given the seriousness of damages, putting people’s lives potentially at risk, there are many situations where SMCRA classify these events as Priority 1. Meier and Gibson also stress that it is particularly important to disseminate information to residents, estate agents, community leaders and municipal authorities on the impacts of subsidence, especially in areas which are already occupied, or undergoing urban and/or rural expansion. This has to be done in a comprehensive and effective way so as to protect existing assets. Information is conveyed via educational material which is normally produced and published by the Illinois State Geological Survey.

When residents or property owners suspect the occurrence of subsidence in their properties, they are advised to get in touch with the Illinois Department of Natural Resources which co-ordinates a state-wide programme on abandoned mines (Abandoned
Mine land and Reclamation Program). According to Bauer (2008), problems usually associated to subsidence relate to the local conditions of the soil, the change in inclination of paving surfaces associated to the period of use, structural problems in wall-supporting beams and the expansion of bricks. Experienced professionals visit the site in order to determine whether there is a relationship between the problem highlighted and the existence of inactive mines. If there is evidence of potential threat to people’s lives due to the subsidence of underground mines, these professionals are responsible for obtaining federal government funds to mitigate the danger (BAUER, 2006).

Meier and Gibson (2004) observe that in Illinois there is some divergence between the amount of surface damage and the public’s response in terms of awareness about this issue. They argue that in most cases subsidence occurs in isolation and affects few people, in contrast to natural disasters (earthquakes, floods and large storms) which affect a considerable amount of people in a short time period and awaken public awareness. Furthermore, subsidence is not a sufficiently cataclysmic event so as to mobilize public support for a political solution to this issue.

Ruiz (1996) states that some environmental groups have a significant role in disseminating information on the impacts of subsidence in Illinois, in particular Stewardship Alliance (former Illinois South Project, Inc.), despite the criticism of specialists from the Illinois Department of Natural Resources, Office of Mines and Minerals. These specialists argue that this NGO provided alarmist reports to the media. According to Valiati (2013), the population of the coal regions of Santa Catarina is not officially informed by either the companies or competent authorities on areas which were previously the site of underground mining activities. Furthermore, there are no reliable records on the state of the subsoil in inactive underground mines and, therefore, the region does not possess risk zoning maps related to this phenomenon either for rural or urban areas.

Menezes (1995) highlights that the dissemination of information on subsidence should be the responsibility of the body conducting Geological Services in Brazil, given that in Illinois this is the responsibility of the Illinois State Geological Survey. However, it is believed that other mineral sectors and environmental control organizations, as well as NGOs, should also play a part in this process. Ramos (1995) stresses that the dissemination of information should assist the elucidation of facts to the public and conciliate the interests of communities affected by subsidence and those of mining companies. According to Valiati (2013), another obstacle in attributing responsibilities with regard to the Santa Catarina coal basin is proving the relationship between underground coalmining and damages caused in surface infrastructure, in particular damages to buildings and the disappearance of water sources. Generally speaking, mining companies require evidence of this relationship. They allege that it is common for damages to be caused in civil construction because of poor construction practices which happen without technical supervision. Similarly, it is also common for companies to use these allegations as justifications. Conflict resolution is more difficult because of the costs complainants have to bear. Often, they do not have sufficient financial means to prove, with the assistance of technical reports, the relationship between mining and the damages claimed. Surface occupiers alleging damages to their properties because of coalmining must lodge a complaint with
the DNPM. Experts will then carry out an inspection in the area of the complaint and issue an Inspection Report. If the report concludes that there is a relationship between the damages claimed and underground coalmining, the DNPM, which has had offices in the region since the 1980s, sends an official report to the property owner, requiring that, in accordance to the Mining Code, the mining company recover the damages caused or provide compensation (VALIATI, 2013). If problems are not resolved by the company, complainants can use this report to pursue indemnity proceedings. When subsidence causes damages to homes, threatening people’s safety, the mining company has to move the residents out until the problems are resolved (VALIATI, 2013). Most documents related to coalmining are available in the DNPM office in Criciúma, and some older documents are kept in the DNPM's headquarters in Florianópolis. The public is allowed informal access to these documents if mines are planned beneath their properties. However, a copy of the documents can only be provided with the permission of the District Head if it is formally requested or via a judicial decision (VALIATI, 2013).

Many environmental organizations in Brazil have had a significant role in disseminating information and promoting public awareness on the negative impacts of coalmining, including subsidence. According to Santos (2008), the following organizations stand out: Criciúma Association for Environmental Protection [APACRI], the NGO Sócios da Natureza in Araranguá, Rio Albino Community mobilization against the setting up of the Nova Beluino mine in Siderópolis and Morro do Estevão, and Albino Ecological Awareness (CEMEA).

3) Establishing subsidence insurance in areas at risk of subsidence could guarantee that damages to households are mitigated

The Illinois Mining Subsidence Insurance Fund was established by state legislation in 1979 as a way of accepting the risk of potential environmental damages which could result from mine subsidence. This measure has been discussed by a number of authors (BAUER, 2008; BAUER, 2006; MEIER; GIBSON, 2004; BAUER et al., 1995; GRAY, 1990; DUMONTELLE et al., 1981). The purpose of the Illinois Mining Subsidence Insurance Fund is to protect properties situated in areas threatened by the subsidence of both abandoned and active coal mines. It is particularly important for residences on or near mines operating before 1997 (the year in which SMCRA was approved) given that mining companies may no longer exist, making it impossible to assign liability for damages caused (BAUER, 2008). The maximum limit for covering subsidence damages is the same set by insurance companies for losses due to fire or hurricanes. However, there is a maximum re-insurance amount available to insurance companies through the Fund, from the 1st July 2011; for homes and commercial buildings this limit was US$750,000. The maximum re-insurance amount for households is US$15,000 (ILIINOIS MINE SUBSIDENCE INSURANCE FUND, 2013).

According to Bauer (2008), the 1979 Mine Subsidence Insurance Act established subsidence insurance for the state of Illinois as part of residential property policies. In counties where 1% or more residences are sited above inactive underground mines,
subsidence insurance is automatically added to policies. Property owners who refuse this cover are asked to sign a liability clause (BAUER, 2006). When residents suspect damages caused by subsidence in properties, they can immediately contact their insurance company which will be responsible for inspecting the property. According to Valiati (2013), at the request of the Public Prosecutor’s Office (PPO) coalmining companies sought to insure themselves against this type of event. However, in Brazil coalmining companies did not manage to find an insurance company willing to work with these types of claims. Valiati argues that in Santa Catarina it would be advantageous to implement a subsidence insurance system, similar to the Illinois system. This would improve relations between mining companies and occupiers of land on or near mining areas, and there would be a reduction in the number of subsidence-related legal proceedings. However, in the Santa Catarina coal region, difficulties relating to proving the link between surface damage and coalmining when assessing damages are frequent (VALIATI, 2013).

**Final considerations**

The most important lessons learned with regard to Santa Catarina relate to the need to have detailed knowledge of the coal region's mining sites in order to disseminate information about the risks of subsidence as widely as possible to all interested parties and establish a mechanism for providing subsidence insurance to the population. These lessons are the result of bringing together the opinions of various experts on this matter, both in the context of Brazil and the USA. In Illinois, all these lessons have become routinely internalized by residents, companies, organizations, institutions and the public authorities in the coalmining region. However, in Santa Catarina in Brazil, despite some attempts at replicating actions carried out in the US state, they were invariably less effective than expected and as would be necessary to address the problem of risk to human lives, either by public authorities or the companies themselves.

Indeed, an analysis of the lessons learned from the case in Illinois show that there are no innovations which could be applied to the coal basin regions of Santa Catarina. US practices were clearly discussed in Brazil. This is reflected both in the analysis of technical studies found in the literature and interviews with Brazilian experts. Thus, in order for these lessons to become more than mere intentions, only addressed in academic debates, public authorities must act in a coordinated manner. Given that subsidence is a phenomenon affecting an isolated group of specific residents, and only sporadically, there is a tendency that both the media and the government pay scant attention to this issue in comparison to risks associated to other natural or man-made phenomena, such as landslides and floods. This study reveals that, despite an interval of eighteen years between interviews with specialists, this subject matter remains up-to-date and relevant. Little has been done to effectively reduce conflicts related to the subsidence of mines in the coal-producing region of Santa Catarina.
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Addressing socio-environmental conflicts in cases of coal mine subsidence in Brazil and the USA


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Addressing socio-environmental conflicts in cases of coal mine subsidence in Brazil and the USA


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Abstract: This paper analyzes social and environmental conflicts associated to the impacts of coal mine subsidence in Santa Catarina, Brazil and Illinois, USA, in order to identify the “lessons learned” by the agents involved in the implementation of subsidence regulation in Illinois that may be relevant for future environmental management of affected areas in Brazil. Illinois has considerable experience in subsidence because 2.8% of its area has been mined for coal. It is assumed that conflicts represent obstacles to sustainable development in the coal mining region of Santa Catarina. The methodology involved a literature review, questionnaires and interviews conducted with specialists in the coal mining industry. The most important lessons to draw from Illinois refer to the need to have thorough knowledge of the underground areas mined for coal so as to convey clear and objective information regarding the potential risks of subsidence. In addition, it is also important to offer subsidence insurance to the population.

Keywords: social and environmental conflicts, underground mining, subsidence, environmental impacts, sustainability.

Resumo: Este trabalho analisa os conflitos socioambientais relacionados aos impactos de minas subterrâneas de carvão em Santa Catarina, Brasil, e Illinois, EUA, visando identificar “lições apreendidas” por participantes do processo de implantação de regulamentações de subsídia naquele estado americano que possam ser relevantes para a gestão ambiental em áreas impactadas por este fenômeno no Brasil. Illinois tem uma vasta experiência no assunto por ter 2,8% do seu território minerado por carvão. No Brasil assume-se que os conflitos decorrentes de subsídia representam obstáculos ao desenvolvimento sustentável da região carbonífera catarinense. A metodologia do estudo consistiu em revisão da literatura, aplicação de questionários e realização de entrevistas com especialistas em mineração de carvão. As lições apreendidas mais importantes para Santa Catarina referem-se à necessidade de conhecer detalhadamente as áreas da região carbonífera que foram
mineradas subterraneamente visando veicular informações claras e objetivas sobre os riscos da movimentação das superfícies, além de oferecer seguro de à população.

Palavras-chave: Conflitos socioambientais; Mineração subterrânea; Subsidência; Impactos ambientais; Sustentabilidade.

Resumen: Este artículo analiza los conflictos socio ambientales relacionados a los impactos de de minas subterráneas de carbón en Santa Catarina, Brasil, y Illinois, EUA, con el fin de identificar las lecciones aprendidas por los participantes del proceso de implementación de los reglamentos de subsidencia en el estado norte americano que pueden ser relevantes para la gestión ambiental en áreas impactadas por este fenómeno en Brasil. En Illinois se adquirió una vasta experiencia en el abordaje de los conflictos derivados de la subsidencia visto que 2.8% de su territorio es ocupado por minerías de carbón. Se supone que estos conflictos representan obstáculos al desarrollo sostenible en la región carbonífera brasilera de Santa Catarina. La metodología del estudio consistió en una revisión de la literatura, encuestas y entrevistas con especialistas en minería de carbón. Los aprendizajes más importantes para Santa Catarina se refieren primeramente a la necesidad de conocer adecuadamente las áreas de la región que fueron mineradas subterráneamente. Ese conocimiento permite transmitir informaciones claras y objetivas acerca de los riesgos de subsidencia y ofrecer seguro a la población.

Palabras clave: Conflictos socio ambientales; Minería subterránea; Subsidencia; Impactos ambientales; Sostenibilidad.