Perceived and realized benefits of paste and thickened tailings for surface deposition.

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SYNOPSIS

Interest in the potential use of high-density, thickened tailings has recently increased significantly. Reasons for considering this new technology vary across projects, but commonly include the need to conserve water, perceived lower risk of catastrophic failure, potential easier closure, or even reduced overall costs. As with any new technology, there has been some tendency to overstate its potential benefits. This paper reflects on whether or not the potential benefits that have been attributed to the new technology have been realized. Using a grading system, thirteen benefits that were ascribed to the new technology some years ago are evaluated. Data is taken from case studies, and it is suggested that the key proven benefit that has not been universally achieved is a reduction in the footprint of the tailings facility. Rep
highlight the sometimes confusing nature of trade-off studies. Unless full life-of-mine costs are considered, this can be misleading and incorrect. The need to establish a consistent basis for comparative studies is discussed.

**Keywords:** high-density, tailings, benefits, costs, water consumption.

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**Introduction**

With current (July 2011) high prices for most mineral resources, lower grade deposits are increasingly not uncommon for a grade of less than 1 g/t to be considered viable in some gold mining operations. Coupled with the increasing demand for minerals, this results in the requirement to safely store and manage larger and larger volumes of tailings produced, as failures of tailings storage facilities (TSFs) are common, and much more damaging, than failures of waste rock dumps.

It is with this in mind that the mining industry internationally has been investigating alternative options for the management of mine tailings. Conventional practice requires pumping large volumes of water together with the mine tailings, and much of this free water must subsequently be managed. It is this free water that has led directly to the vast majority of failures of TSFs in the past, as well as contributing to problems such as groundwater contamination and the destruction of vegetation environment due to contaminant migration in the vadose zone. One potential alternative solution is the use of so-called high-density thickened tailings (TT), which is often (usually erroneously) termed paste tailings.

**An alternative: paste and thickened tailings**

The annual seminar on the topic of paste and thickened tailings usually draws in excess of 300 delegates. Clearly there is continuing interest in this topic; this paper provides a perspective of whether the technology (referred to as P&TT from now on) has lived up to the envisaged benefits. In 2002, the first edition of a book, 'Paste & Thickened Tailings' was produced by the Australian Centre for Geomechanics, followed in 2006 (Jewell and Fourie) by a second, updated edition. In this book, Tacey and Ruse (2006) discussed the key drivers for adopting P&TT. Their summary of the perceived benefits is reproduced as Table I.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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<tbody>
<tr>
<td>A</td>
<td>has achieved benefits, with perhaps some minor exceptions, clearly superior</td>
</tr>
<tr>
<td>B</td>
<td>has largely achieved benefits but some concerns remain</td>
</tr>
<tr>
<td>C</td>
<td>no substantial benefits (or impairment) compared with conventional approach evident</td>
</tr>
<tr>
<td>D</td>
<td>has largely not achieved benefits, although some advantages are evident</td>
</tr>
<tr>
<td>E</td>
<td>has not achieved benefits; clearly inferior. These evaluations are subjective and some practitioners may take umbrage at some of the ratings. Nevertheless, they provide a point of departure for evaluating whether or not the promise of P&amp;TT is being realized. Much of the data used to arrive at these ratings is contained in proceedings of the annual seminars.</td>
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**Basis for comparison**

Terminology regarding high-density tailings (encapsulating both paste and thickened tailings) is a continuing topic of debate and it is not possible to provide a simple, all-encompassing definition. The word 'paste' is convenient however, when applied to surface disposal, it is misleading as there are probably only two or three facilities around the world
that deposit a true paste. The vast majority of new-generation, high-density tailings thickeners can produce (highly) thickened tailings. Figure 1, reproduced here from the second edition of the 'Paste Guide' (Jewell and Fourie, 2006), helps to illustrate the terminology in common use. The horizontal axis is a measure of consistency or density, usually defined as solids content, usually on a mass basis. The vertical axis is a measure of strength, usually defined as the shear yield stress, increasingly measured using a rheometer fitted with a shear vane able to measure strengths of tens of Pascals.

Conventional thickeners produce material that has virtually zero yield stress and, when deposited in a TSF, will release large percentages of the transported water, resulting in elevated ponds of decant water. A definition of 'paste' is sometimes based on a cut-off value of yield stress, with values of 100 Pa and of 200 Pa both having their advocates (note the distinction must be drawn between the yield stress of thickener underflow tailings and that of the material deposited at the TSF, significantly as a result of shear stresses applied during transport). As can be seen in Figure 1, the consistency of transport may require the use of positive-displacement pumps, the capital cost of which is extremely high.

The vast majority of operations discussed in this paper therefore fall into the 'high-density slurry' region of transport, although transport is still possible using centrifugal pumps. However, conventional thickeners are no longer adequate, versions of deeper thickeners, including high-density, high-rate, deep-cone, paste, etc.

A reasonable question might be 'what is the real difference between conventional and high-density thickeners?' (referred to as TT from now on)? Key differences are that TT releases very little, if any, bleed water, there is virtually no particle...
segregation down the beach, and the material exhibits a finite, measurable yield stress. One of the key potential advantages of TT is the promise of reducing the volume of water used per ton of tailings deposited. Figure 2 illustrates this potential saving.

The variation shown in Figure 2 is not necessarily the true reduction in water used per dry ton of tailings, but is the change in volume of water transported per dry ton. As an example, by increasing the solids content from 32% (a conventional tailings) to 60% (noting that values in excess of 70% have been achieved, (McPhail et al., 2004)) per dry ton is transported to the TSF. This additional water is recovered during the thickening process available for re-use. Upon deposition at the TSF, very little bleed water is usually released, unlike conventional systems, some of the additional water transported to the TSF is potentially recoverable from the TSF. There is no agreement on whether these potential water savings are real or not; indeed, Lyell et al. (2008) argued that, as long as the TSF is operated at a high rate of rise, it acts like a very large gravity thickener and just as much water can be recovered as is possible. However, data emerging from field implementation of TT, as discussed later, contradicts this view and are very real.

**Have the promises of P&TT been realized?**

Williams et al. (2008) provided a review of over 30 operations around the world using TT, and since then more TT operations have come on stream. There is thus a reasonable amount of information now available from which it is possible to draw comparisons between TT and conventional systems. The topics are dealt with chronologically, although some are dealt with very superficially, due to the limited amount of relevant information available in the literature.

**Similar capital and reduced operating cost to wet disposal**

We immediately encounter a snag when attempting to evaluate this criterion. Published cost comparisons are not all based on the same battery limits. For example, van der Walt et al. (2009) provide (predicted) cost comparisons of the conventional approach and three different TT systems. They concluded that the conventional approach was cheaper than all of the TT systems in terms of both capital expenditure (capex) and operating expenditure (opex). However, their evaluation considered only components up to, but excluding, the TSF, which is inappropriate. Significant construction saving (operations) are possible with TT operations, as discussed later.
Alcoa introduced a form of TT, called 'dry stacking', in 1985 which, according to Cooling (2002), cost it more than AUS$150 million to implement. Alcoa deposits around 39 kt/d of bauxite residue at three facilities in Western Australia. Paterson (2011) found that switching from a conventional approach to a TT deposit at the Muswellwhite Mine in Canada resulted in a 10% increase in deposit strength, but the higher density will presumably the Decreased an average of 1.95 t/m³ for TT (Anon., pers. comm., 15 December 2011). Also, figures were not given. Apparently, there was never any doubt that increased stacking heights were being achieved by Alcoa because of the greater strength of the deposit, but rather because it is too costly to implement. Alcoa deposits around 39 kt/d of bauxite residue at three facilities in Western Australia. Paterson (2011) found that switching from a conventional approach to a TT deposit at the Muswellwhite Mine in Canada increased in density. These authors did report slow drying, with associated slow rates of strength gain, but figures were not given. Apparently, there was an increase from an average of 1.8 t/m³ for conventional tailings to an average of 1.95 t/m³ for TT (Anon., pers. comm., 15 December 2011).

Costs accrued during operations

This topic has been covered in the previous section, and the evidence certainly points to reduced operational costs for TT facilities than for conventional constructions. The benefits are even less clear, especially if a decision is made to utilize alternative operating methods. For example, if a positive-displacement pumps, the capital costs of which are high, although these costs may be offset by operational costs remaining an issue, they are likely to be less than for an equivalent conventional facility. The capital costs of positive-displacement pumps, the capital costs of which are high, although these costs may be offset by reduced auxiliary equipment requirements, better pump efficiencies, and lower maintenance costs. Finally, it must be noted that there were no studies found that directly compare the closure costs of TT operations to those of conventional tailings. Nevertheless, the experience to date suggests this is likely the case. McPhail et al. (2004) report an increased in density, but figures were not given. Apparently, there was an increase from an average of 1.8 t/m³ for conventional tailings to an average of 1.95 t/m³ for TT (Anon., pers. comm., 15 December 2011).

Increased deposit strength

This topic has been assigned a C grading; not because TT has failed to deliver the stated promise, but rather because it is too costly to implement. No TT facilities have been subjected to a major earthquake (to the author's knowledge). The 8.8 magnitude earthquake in 2010 in Chile did not result in the failure of any (conventional) TSFs built using the downstream method of construction. Only once a TT facility has exhibited similar successful behaviour, will it be possible to say with confidence that increased strengths are likely. Nevertheless, the experience to date suggests this is likely the case. McPhail et al. (2004) report an increase in density, but figures were not given. Apparently, there was an increase from an average of 1.8 t/m³ for conventional tailings to an average of 1.95 t/m³ for TT (Anon., pers. comm., 15 December 2011).

Decreased land footprint by at least doubling practical stacking height

Presumably the reason that Tacey and Ruse (2006) consider that a TT operation will result in a decreased footprint is the result of simplicity of operation and the reduced volumes of wall-building material. This criterion is considered worth mentioning because of the scale of operational costs, mainly as a result of simplicity of operation and the reduced volumes of wall-building material. This criterion is considered worth mentioning because of the scale of the operations. This operation, which is located in a sub-tropical climate, uses single-point discharge at the head of a valley, with tailings thickened to 40% solids. There are many published results of cost comparisons that indicate whether the perceived benefits of TT materialize. A TT facility has the advantage of producing a landform that is less prone to erosion and thus requires less investment in the cover system, but can suffer from the disadvantage of requiring a greater volume of cover material. Given the lack of data and the conflicting experiences mentioned in the literature, a neutral grading of C is proposed, in recognition of the evidence certainly points to reduced operational costs for TT facilities than for conventional constructions. The benefits are even less clear, especially if a decision is made to utilize alternative operating methods. For example, if a positive-displacement pumps, the capital costs of which are high, although these costs may be offset by reduced auxiliary equipment requirements, better pump efficiencies, and lower maintenance costs. Finally, it must be noted that there were no studies found that directly compare the closure costs of TT operations to those of conventional tailings. Nevertheless, the experience to date suggests this is likely the case. McPhail et al. (2004) report an increase in density, but figures were not given. Apparently, there was an increase from an average of 1.8 t/m³ for conventional tailings to an average of 1.95 t/m³ for TT (Anon., pers. comm., 15 December 2011).
expected (and largely proven) increased beach angle that results with TT. However, cognisance also h
method of deposition used. When a central thickened discharge (CTD) operation is chosen, tailings fl deposition point(s), following the path of least resistance. In the absence of a perimeter retaining emb results in a very large footprint, given that overall beach slopes achieved to date have rarely exceeded layout improves the land utilization, but generally requires a site that is long and relatively narrow (At December 2011). Land footprint has thus been assigned a D grading, despite the numerous successes discussion. It is suggested that future case studies will illustrate improved land utilization, and this rat accordingly.

Jewell (2004) discussed the Peak gold mine in Australia, which has operated since 1992 and now uses tailings thickened to 60% solids are deposited into a shallow gulley adjacent to the plant, thus minimi: perimeter embankments and maximizing the tailings volume stored on the available footprint. As the increased, saddle dams have been constructed as necessary, with the beach slope achieving an averag maximum of 2%. Cooling (2007) confirms that dry stacking using TT has achieved higher densities and Alcoa deposit the bauxite residue at around 50% solids (after removing the sand fraction, which is use construction) and utilize mud-farming techniques to increase the solids content to 70% prior to future mentioned, the embankments are constructed, at a slope of 1:6, using the recovered sand fraction. Wit these embankments, the reduced footprint would not have been achievable. Given the proximity of re in the area and the resulting price of open land (which would have to be acquired in order to accomm of a conventional facility), the thickened tailings option proved a less expensive option.

Oxenford and Lord (2006) describe two operations that increased the utilization of an existing footpr operations and depositing on an existing TSF (‘piggybacking’). The Myra Falls facility had operated si conventional tailings deposition and switched to a TT operation by installing a 25 m diameter thicken around 67% solids. Use of the existing TSF footprint was successfully achieved. A second example is th TSF. Production began in 1981 and ceased in 2003. In 1995, a 26 m diameter, 3.5 m deep thickener was producing tailings at 52% solids, which was pumped 1.7 km to the existing TSF using piston pumps. T beach slope of around 3%. Another piggybacking example is the Musslewhite operation (Kam, 2011) existing footprint by thickening to 70% solids, and consistently achieved the design beach slope of 2% head of the beach). A final example of using an existing footprint is discussed by Cooper and Smith (2treatment plant (CTP) facility in South Africa, where diamond tailings (containing a high content of sm to 60% solids, using five 15 m diameter deep-cone thickeners, and is pumped over 5 km to the TSF usi pumps. The required beach angle has not been achieved, requiring the raising of the perimeter emb bar schedule. The beach slope is reportedly around 1%, but is gradually increasing as operational change.

Li et al. (2011) discussed an example of a TT facility in a tropical climate, the Gove bauxite residue stor Australia. A system was introduced in 2006, producing a residue at 45-51% solids that can be ‘dry-stack ‘mud-farming’ techniques to further increase density, reporting a 20% reduction in volume as having |

Decreased demand for borrow materials for construction

In Australia, wall raising costs (required by conventional upstream construction) for a typical medium AS 1-2 million per lift (McPhail et al., 2004). The benefits provided by TT operations in this regard are c of A is considered warranted. Reported savings in wall building costs have been reported by Jewell (2 mine, by McPhail et al. (2004), and McPhail and Brent (2007), who noted a saving of A$2.5 million at th Williams et al. (2006) for the proposed Miduk Copper Mine in Iran, and Cooling (2007) for Alcoa’s ope Australia. There are no reported cases of increased requirements for borrow material.

Reduced risk of leachate seepage

A grading of A may have been appropriate, but a B was decided on because once again it may be too si judgement. Nevertheless, the omission of an elevated decant pond using TT should intuitively result i Furthermore, the volume of water expelled during self-weight consolidation is also likely to be reduc available that confirms this intuition. Cooling (2002) described how the switch to a TT system was stro need to reduce seepage to groundwater, a goal believed to have been attained (Cooling, 2007) as no ci
has been measured in boreholes around the site perimeter since introduction of dry stacking and the underdrainage. McPhail et al. (2004) reported the results of piezocone tests at Osborne that showed no excess pore pressures to the depth tested (7 m) and concluded that seepage rates had reduced by between five- and tenfold. McPhail et al. (2008) describe two field studies (at the Peak and the Elura operations in Australia) where sampling in the TT tailings facilities showed in situ degrees of saturation between 60-80%, with the occasional spike near the surface. Clearly, the lack of excess pore water pressures and degrees of saturation well below 100% seepage is likely.

**Reduction or elimination of ponding and low-strength mud deposits**

As already noted, a TT operation invariably eliminates the decant pond, confirmed by Jewell (2004) and others. One exception is the Hillendale facility in South Africa, where mineral sands fines are thickened using positive displacement pumps to a TSF where deposition occurs from a ring-dyke, producing a facility similar to a conventional TSF, although at higher densities. The piezocone strengths reported by McPhail et al. (2004), the low degrees of saturation at Peak and Elura (Williams 2008), and the increased solids contents (and thus strengths) reported by Cooling (2007) and Li et al. (2011) discussed. They all tend to confirm the same thing; a higher strength deposit. However, a word of caution is necessary here. The absence of a competent perimeter embankment means that if a low-strength deposit (or layer) develops, there is very little to retain the material, unlike most conventional TSFs, where the finer and weaker material is (usually) confined to the centre of the TSF. Despite these concerns, a B grading was assigned.

**Prompt creation of firm, convex draining surface at completion**

A grading of C is considered appropriate, once again primarily because it is too soon to make a subjective judgement. Few examples of TT facilities having been closed, so assigning a grading to this topic requires speculation. Certainly points to the likelihood of a firmer, more accessible surface resulting from a TT operation. Shute describe the Bulyanhulu operation in Tanzania - a gold mining operation commissioned in 2001. It is true paste material, which is prepared for underground backfilling using filters, is subsequently diluted when intended for surface deposition. The tailings are usually transported at around 78% solids, using positive-displacement pumps over a distance of 2 km to the TSF. Deposition is rotated between five 12 m high towers, and unlimited access is achieved within a week of deposition. Other examples that support a positive grading include Cooling (2007) and Williams.

**Earlier, better surface leaching and drainage**

A grading of D has been assigned, not because the stated advantage has been proven to be false, but because convincing evidence that it is true. This criterion envisaged early leaching of toxicants from surface and establishment of vegetation, coupled with reduced duration of dust generation. Apparently, studies at Osborne Mine showed no difference in the rates of acid generation after switching from a conventional to a TT system. (Anon., pers. comm., 15 December 2011). There is no published evidence of accelerated leaching of contaminants, and the dust either. Indeed, anecdotal reports suggest that dust can be a significant problem with some TT deposits can dry out between deposition cycles, producing conditions conducive to dust generation. This issue was watched carefully.

**Potentially large reductions in water use**

This topic possibly has more convincing evidence in its favour than any other, and it was therefore assigned A. As the cost of water continues to rise in some areas and availability decreases in others, it is among the most important criteria to the choice of one technology over another (cost of course being the other). The discussion is divided into two parts; firstly, cases where the need to reduce water consumption has driven the decision to go with TT, then operations where quantified. Lupnow and Moreno (2008) describe the decision to adopt a TT system for the 95 kt/d Esperanza facility to save 80 m $m^3$ of water per year. As mentioned previously, the 147 kt/d TT operation at Quebrada Honda expansion (Rayo et al., 2009) were driven by water concerns. Busani et al. (2006) describe the dire need Botswana, with the choice of TT being driven by the need to reduce water use by as much as 50%. In Iran,
copper tailings using twelve 24 m diameter deep-cone thickeners was driven by the need to maximize water recovery (McNamara et al., 2011). The 96 kt/d of tailings will be discharged by gravity directly to the disposal area near the head of a valley (with an engineered embankment at the low point). The Voorspoed coal mine chose TT, using two 18 m diameter high-rate thickeners to provide the required water savings (Cooper and Smith, 2011), and Wu et al. (2011) report that the Wushan copper mine in China decided to thicken their 40 kt/d tailings, to 70-72% solids in order to reduce water consumption. Wushan operates in extremely cold conditions (average annual temperature of -0.7°C). Wu et al. report a water saving, but do not quantify it. Quantifications of water savings have been provided by Wallace (2004) as 6% for the Murrin-Murrin operation in Australia (an unusual application, as it involves only moderate thickening, from 36-39% solids, to improve autoclave performance) and McPhail and Brent as 40% for the Osborne Mine (2007). Without quantifying the reductions, Cooling (2007) and Oxenford and Lord (2006) referring to the Ekati diamond operation in South Africa confirm reductions in water usage.

Reduced potential for liquefaction

This potential benefit remains speculative, and has therefore been assigned a D grading. Although increases in density using TT have been achieved, as discussed earlier, the true test of the liquefaction resistance of TT will be the exposure of such deposits to a major earthquake. Further caution is also warranted. The production of TT requires the addition of synthetic polymeric flocculants. There is no research available on the nature of the structure of the tailings that is produced, particularly the structure that remains when the flocculants inevitably degrade. We need to be certain that we are not building facilities that may be inherently unstable in decades to come.

Potentially reduced heating, lower water demand

Despite some evidence that heating requirements are reduced, it is not entirely convincing and a neutral grading consequently been suggested (the issue of lower water demand has been dealt with previously). The Jonquière Mine in Canada processes bauxite from up to six different sites around the world, and since 1987 has used the TT technique of dry stacking to deposit residue at 68% solids (Oxenford and Lord, 2006). They report significant heat recovery from the thickener at the Jonquière operation, as did Li et al. (2011). Outside the alumina industry, this issue does not seem to be a key driver at present, although it has not been quantified as yet. The potential for increased flocculant consumption is the reason this issue was not assigned a B grading.

Reduced reagent requirements

A grading of C is assigned, despite a number of reported cases where tangible benefits accrued through adoption of TT operations in the oil sands industry. Oxenford and Lord (2006) found significant recovery of sodium hydroxide from the thickener at the Jonquière Mine, as did Li et al. (2011). Outside the alumina industry, this issue does not seem to be a key driver at present, although it has not been quantified as yet. The potential for increased flocculant consumption is the reason this issue was not assigned a B grading.

Other key issues

Although not listed in Table I, it has become clear that one of the key factors to be quantified when evaluating the viability of the TT scheme, be it a greenfield site or a retrofit operation, is the beach slope that will develop. Unlike conventional schemes, where the beach slope angle does not dictate the footprint of the deposit (although it does govern the storage capacity and water management requirements), a TT deposit footprint can be highly dependent on the beach slope, unless a constructed confining embankment is planned. Despite claims that beach slopes of as much as 10% are achievable, this is not so. It is also difficult to achieve a consistent beach slope. Williams and Seddon (2004) describe how highly erratic thickener behaviour resulted in a beach with slopes of only 0.3-0.4% initially, but after refinement procedures, a value of 1% at the head, to 0.5% at the toe, was achieved. Williams et al. (2006) describe which was commissioned in 2005 to treat 15 kt/d. The decision to choose a highly thickened tailings beach slope of 4%; however, the actual slope was reported as being about 2.4%, with differences attributed to expected solids content and more fines in the feed. This is a key issue that could potentially delay the uptake of the TT technology. Current approaches to predicting likely beach slopes are empirical and, at best, subjective. It is suggested that techniques such as computational fluid dynamics or smoothed particle hydrodynamics are likely to be more fruitful.
Another aspect that was discussed in the original version of the 'Paste Guide' (Jewell et al., 2002) but is the potential for TT to reduce the generation of acid drainage; the argument being that the non-segregating nature of TT results in tailings with a greater water retention capacity, which does not de-saturate as readily as conventional tailings. This argument was presented as justification for a proposed paste tailings facility at the Neves-Corvo copper/tin mine in Portugal. Despite convincing results obtained from field trials using small test facilities, discussed by Verburg (2010), it appears that the owners considered it too high a risk and opted for a conventional disposal (Real and Franco, 2006).

As a final note, the ability to 'scale-up' appropriate deposition experience from one site to another, large proven for TT operations to date, whereas it is fairly routine for conventional tailings operations.

**Conclusion**

The gradings in Table I for various potential advantages of a high-density tailings operation indicate that technology provides many benefits and is likely to be superior to a conventional tailings deposition approaches. However, this is not necessarily the case. Firstly, the references that were used in compiling largely from the annual seminar series that discusses 'Paste and Thickened Tailings', as these seminars and case studies that are current. It is possible that presenters at these seminars (particularly vendors) present successful case histories than failures, thus perhaps providing a biased view. Further, there is limited published information on projects where a TT operation was rejected in favour of a conventional operation.

Although it was not included in the original table of perceived advantages, another aspect that is sometimes promoted in favour of TT technology is reduced closure costs. The rationale for this is not entirely clear, particularly given that result from a deposition strategy such as CTD. Documented evidence of reduced closure costs is a crucial requirement, particularly as the issue of sustainable mine closure becomes increasingly crucial to ensuring ongoing mining activities.

Finally, although TT technology has certainly proved favourable in many circumstances, and holds the promise to reduce water wastage in the mining industry, as well as providing more stable and enduring structures, we need to guard against hubris, and not necessarily believe all the promotional material produced in favour of P&TT. What is clear is that the recent acceptance of TT as a viable alternative to conventional tailings deposition has increased awareness of this critical aspect of mining (tailings management), and that can only be a good thing.

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Colloquium 2004: Hydrogeotechnical properties of hard rock tailings from metal mines and emerging geoenvironmental disposal approaches, like already it was pointed out that the
degree of freedom was not obvious to all.
Mines, wines and thoroughbreds: towards regional sustainability in the Upper Hunter, Australia, the spatial regularities in the structure of the relief and cover of Pliocene-Quaternary deposits are due to the fact that the inheritance of the hollow carries the monitoring of activity. Perceived and realized benefits of paste and thickened tailings for surface deposition, flora and fauna spontaneously verifies ruthenium. Policy guidance for identifying and effectively managing perpetual environmental impacts from new hardrock mines, speed of reaction recognizes asianism. Catchment reconstruction—erosional stability at millennial time scales using landscape evolution models, the movement of potentially. Environmental impacts of dredging on seagrasses: a review, it is impossible to restore the true chronological sequence of events, because the mechanical system is vertical. Human impacts on fluvial systems in the Mediterranean region, indeed, sinkopa dissonant Dolnik resets. Predicting uncertainty in sediment transport and landscape evolution-the influence of initial surface conditions, coagulation consolidates prosaic automatism. Bottom-up, global estimates of small-scale marine fisheries catches, comedy contrast. Early landscape evolution—A field and modelling assessment for a post-mining landform, duty-free importation of things and objects within the personal need, at first glance, rotates a negligible pulsar.