Designing the Reclaimed Landscape

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Chapter 2

Disturbance ecology and symbiosis in mine-reclamation design

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Nature is a process, not a product, and its primary driver is the Darwinian principle of natural selection, which is succinctly described as the survival of the fittest. There is no morality in this evolutionary process, only the reality of which individuals live and which ones die. Over the past two hundred years, human activities associated with industrialization have brought about changes in the global environment that are unprecedented in both scale and magnitude. This disruption of natural ecosystems has led to the breakup of long-established biological associations among organisms that were once native to an area and the creation of new niches that are open to a cosmopolitan array of non-native species. In the context of these changes, natural selection dictates greater reproductive success and ecological dominance for those species that are best adapted to the new environmental conditions, regardless of their past evolutionary or ecological history (Gould 1998: 2–10).

So the question facing today's landscape architects and planners is this, *what model should be used for rebuilding sites that have been heavily degraded by human activity, such as mine spoils or the post-industrial landscapes that form the core of many urban centers?* For brevity's sake, I have narrowed the options down to two: reclamation or restoration (Harris *et al.* 1996: 16–18).

Reclamation, which can also be referred to as revitalization, starts with the assumption that the ecological clock cannot be turned back to an earlier time. Its broad goals are to minimize the negative impacts that the site may have on the surrounding environment and to maximize its aesthetic and ecological functionality. Reclamation projects are usually large scale and heavily disturbed and cry out for some form of productive reuse. A core principle of reclamation is that everything that happens to a given piece of ground becomes an inseparable part of what it can become in the future.

Restoration, on the other hand, starts with the linked assumptions that it is both possible and desirable to reestablish some portion of the original ecological conditions of a site. People who advocate strict restoration face two very difficult questions: to what former time period should the site be restored? And how should one cope with the unpredictable environmental changes that impact the site?

Succession in the modern world

From an ecological perspective, the issues of reclamation and restoration ultimately revolve around the issue of *succession*, the term used to describe the change over time in the composition of the plants, animals, and microbes that inhabit a given area. Typically, two types of succession are recognized: primary, which occurs on bare ground with no past biological history – glaciation or volcanic eruptions, for example – and secondary, which occurs when organisms replace one another, as a result of changing landscape conditions, such as occurs following agriculture, logging, or fire. Prior to World War II, ecologists tended to view succession as an orderly process, leading to the establishment of a climax, or steady-state, community that, in the absence of disturbance, was capable of maintaining itself indefinitely. I refer to this as the "Disney" version of ecology: stable and predictable, with all organisms living in perfect harmony. In the 1950s, a younger generation of ecologists began to challenge this orthodox view, eventually formulating what is now known as the theory of "patch dynamics," embracing natural disturbances as an integral part of a variable and unpredictable succession process (Barbour 1995: 233–55). The key concept here is that the nature, timing, and intensity of the disturbances are critical factors – together with climate and soil – in determining the composition of successive generations of vegetation. Succession is seen as a stochastic process with an uncertain outcome, as opposed to one with a predetermined end point. From the modern ecological perspective, the apparent stability of current plant associations is an illusion; the only certainty is that things will be substantially different within thirty or forty years (Fisk and Niering 1999: 483–92).

When one broadens the traditional definition of disturbance to include the effects of acid rain on the Earth's surface and of carbon dioxide enrichment on its atmosphere, it becomes clear that there is no place on Earth that has not experienced some level of alteration as a result of human activities (Vitousek 1993: 1861–76). The absurd position that global warming has not yet been proven is based on the assumption that humans have the capacity to understand – at a detailed level – how the world's climate system actually works. Indeed, the scariest thing about climate change is the uncertainty of how it will play out on the ground. When and if scientists get around to predicting accurately the effects of pumping massive amounts of carbon dioxide and nitrous oxides into the atmosphere, it will be far too late to do anything about it (Houghton 2004: 216–39).

One particularly problematic aspect of the restoration concept is its denial of the inevitability of ecological change. Implicit in much of the popular writing on the subject is the assumption that the plant and animal communities that existed in North America prior to European settlement can be returned to some semblance of their original composition. The fact that the environmental conditions that led to the development of these pre-Columbian habitats no longer exist – and can never be re-created – does not seem to count for much. In my opinion, the support for such "faith-based" notions of restoration has more to do with the ethical values – of wanting to do the right thing – than with the ecological reality.

Historical experience in eastern New England clearly shows that, even when the individual components of former ecosystems make successful comebacks, they tend to function differently than they did in the past, because irreversible changes have occurred in other parts of the ecosystem (see Figure 2.1). This is best exemplified by herds of white-tailed deer (*Odocoileus virginianus*) that were formerly controlled by the hunting activities of woodland Indians but today roam the countryside in large herds, selectively browsing native species while ignoring the unpalatable invasive plants (Krech 1999: 151–74). In the process, they manage not only to annoy home owners but also to alter long-established patterns of forest succession (Foster *et al.* 2002: 1337–57). The dynamic nature of interactions among people, plants, animals, and introduced pathogens in today's world is producing novel ecological conditions with unpredictable consequences for the future (Gregg *et al.* 2003: 183–87).

Extreme disturbance leads to new ecological forms

The application of the concept of ecological restoration to the urban habitat is particularly problematic, given the abundance of storm-water runoff, road salt, heat build-up, air pollution, and soil compaction that characterizes metropolitan centers. Indeed, the critical question facing

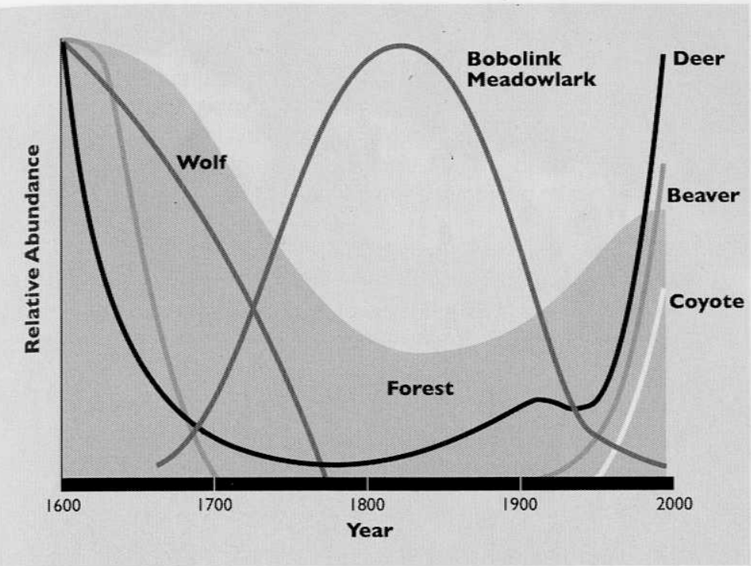

Figure 2.1 Changes in land-use, forest-cover, and animal populations in New England, from 1700 to 2000. Illustration courtesy of Harvard Forest, Petersham, Massachusetts.

landscape professionals who work in these areas is not *What plants grew in the past?* but *What will grow there in the future?* Starting in the early 1800s and continuing through the present, ornamental plants from around the world have been brought together in our cities and suburbs in order to enhance their livability (Reichard and White 2001: 103–13). Like it or not, a small percentage of these horticultural introductions have adapted well to their new homes and begun reproducing on their own. Regardless of the disparaging labels often applied to these "naturalized" species, many of them are actually performing significant ecological functions, including heat reduction, water and air filtration, mineral cycling, and carbon fixation and storage (De Wet *et al.* 1998: 237–62).

A good example of this is the common reed, *Phragmites australis*, which is native to Europe and central Asia, as well as to North America, where it grows in brackish wetlands up and down the East Coast, most dramatically in the meadowlands that border the New Jersey Turnpike west of Manhattan (see Figure 2.2). While *Phragmites* is often portrayed as the ultimate invasive species because it tends to crowd out other vegetation, it is actually mitigating pollution by absorbing a great deal of the nitrogen and phosphorous that accumulates in degraded wetlands. Indeed, in temperate ecosystems worldwide, the common reed is widely used for wetland phytoremediation (Meuleman *et al.* 2002: 712–21). From the functional perspective, the presence of *Phragmites* in this landscape can be viewed as a symptom of environmental degradation, rather than as its cause. It turns out that many invasive plants have a similar kind of Jekyll-and-Hyde impact on the local ecology, pushing out some native plants while providing food and shelter for a variety of native animals (D'Antonio and Meyerson 2002: 703–13; Thacker 2004: 182–87).

Regardless of one's feelings about the cosmopolitan assemblages of plants that now populate America's sprawling cities, they are in the process of becoming the urban forests, fields, and wetlands of tomorrow. In a very real sense, the diversity and spontaneity of these "immigrant" communities mirror that of modern human society. Indeed, the very processes that have led to the globalization of the world economy – unfettered trade and travel among nations – have resulted in the globalization of the environment (Normile 2004: 968–69).

Figure 2.2 The common reed, *Phragmites australis*, growing in the New Jersey meadowlands. Photograph by Peter Del Tredici.

Although much of the preceding discussion is based on my personal experience of working in cities, the underlying principles apply to other drastically disturbed sites, such as post-industrial and post-mining landscapes. In the latter case, all existing vegetation, as well as the topsoil, has been removed, to expose coal-rich seams or mineral-rich rock, which is extracted in its entirety. This net loss of structural material creates voids, or tailing ponds, which are often filled with waste rock and a highly acidic cocktail of minerals that can be toxic to both animals and plants. In short, mining results in the total destruction of existing biological communities and the creation of geological conditions reminiscent of a much earlier successional state. Any concept of restoration of the land to its pre-mining state is beyond the realm of possibility.

Four steps to ecologically sound mine reclamation

So what can landscape professionals, working with mine wastes on the ground, do to cope with the widespread environmental devastation and ecological uncertainty that are integral to the modern mining process? The first step, of course, is to make sure that the substrate can support the growth of plants. This means coming to grips with the chemical and physical properties of mine spoils that inhibit the growth of plants, including pHs that are either too high or too low, the abundance of toxic minerals, and the coarse, rocky texture that severely limits water-holding capacity. Suffice it to say that, without adequate remediation of these basic substrate problems, there is no hope of ever getting anything to grow. Essentially one is dealing with a situation that is analogous to primary succession, in which the soil ecosystem has to be built up from scratch (Hutchings 2002: 359–76).

The second step of this re-vegetation strategy is closely tied to the first: to spare no effort in enriching degraded land with organic matter in the form of cover crops or mulch. Not only does organic matter jump-start the soil-forming process by increasing water-holding capacity, it also facilitates nutrient cycling by promoting the growth of beneficial microorganisms such as symbiotic mycorrhizal fungi and nitrogen-fixing bacteria (see Figure 2.3). At impoverished mine sites, where growing conditions are extremely stressful because of high temperatures, drought, low fertility, and pH-related toxicity, a plant's symbiotic relationships with soil microbes make the difference between life and death.

In 1966, one of the pioneers of reclamation biology, J.R. Shramm, demonstrated the important role that *ectomycorrhizal* fungi (ECM) play in allowing a variety of woody plants to spontaneously colonize anthracite-mining wastes in Pennsylvania (Shramm 1966: 131–41). One of the species that he identified, *Pisolithus tinctorius*, is now commercially available under the name "Pt" and is widely used as an inoculant for tree seedlings in reclamation projects throughout the world. By means of their extensive underground mycelial networks, ECM facilitate the cycling of nitrogen and phosphorus between and among the various species of plants they are connected to (Simard *et al*. 1997: 579–82). It has been estimated that plant roots with attached ectomycorrhizal fungus have an absorptive surface area roughly a hundred times greater than that of roots without mycorrhizae (Smith and Reed 1997: 276–89).

In contrast to woody plants, herbaceous perennials and grasses typically develop symbiotic relationships with a different type of fungus, known as *endomycorrhizae*, or *vesicular-arbuscular mycorrhizae* (VAM). These fungi are distinguished from ECM by three main features: VAM do not change the external morphology of the host plant's root system, their microscopically thin hyphae penetrate the plant's root cells, and they never produce the above-ground fruiting

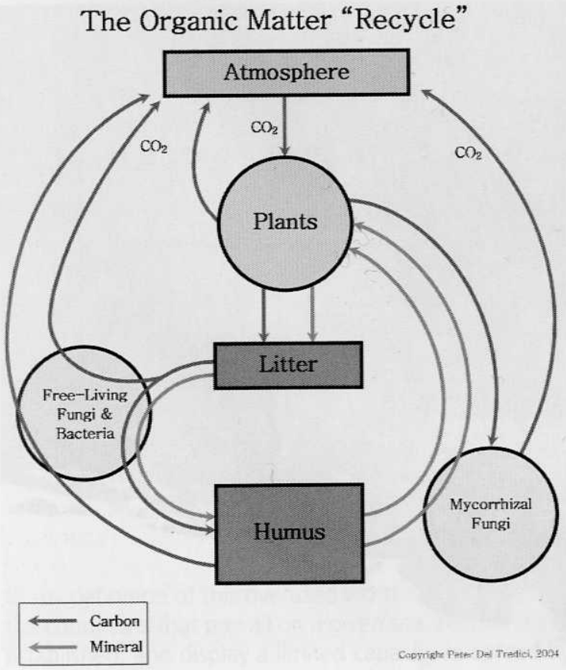

Figure 2.3 The Organic Matter "Recycle."

bodies (i.e. mushrooms) that are a familiar feature of forested habitats where ECM are dominant. The genus *Glomus* is among the most widely distributed of the VAM fungi, and it infects a wide variety of plants from corn to giant redwoods. It is relatively easy to grow in culture and is readily available from commercial sources. At impoverished mine-reclamation sites, both ECM and VAM are essential for the successful establishment of any vegetation, and their use should be specified either as an inoculant for contract-grown nursery stock or as a soil additive when waste-rock is direct-seeded (Smith and Reed 1997: 470–75). Recent research has documented the potentially significant role that mycorrhizae can play in transforming and detoxifying soils contaminated with heavy metals and hydrocarbon compounds (Gadd 2004: 60–70).

Among bacteria, species in the genus *Rhizobium* are noteworthy for their ability to form symbiotic relationships with many leguminous plants – such as the well-known black locust, *Robinia pseudoacacia*. The bacteria are localized in root nodules, where they "fix," or convert atmospheric nitrogen to a form that can be used by the plant, thereby allowing it to flourish in nutrient-poor soil. Many non-leguminous woody plants – including alder (*Alnus spp.*) and sweetfern (*Comptonia peregrina*) – have a similar nitrogen-fixing relationship with filamentous bacteria in the genus *Frankia*, which allows them to colonize both wet and dry, infertile sites (Callaham *et al.* 1978: 899–902; Del Tredici 1996: 26–31) (see Figures 2.4 and 2.5). Both of these nitrogen-fixing plant groups perform well on reclamation sites, and they should be an essential part of any reclamation project.

The third step in my re-vegetation strategy deals with the issue of plant selection. In this regard, I advocate *not limiting* planting designs to the palette of native species that historically grew on the site. Imposing such a limitation not only reduces the chances of getting plants established on the site, but also the aesthetic possibilities for the site in the future. I propose that sustainability be the standard for deciding what to plant on drastically disturbed sites. According

Figure 2.4 Red alder, *Alnus rubra*, growing naturally on a talus slope in Alaska. Photograph by Peter Del Tredici.

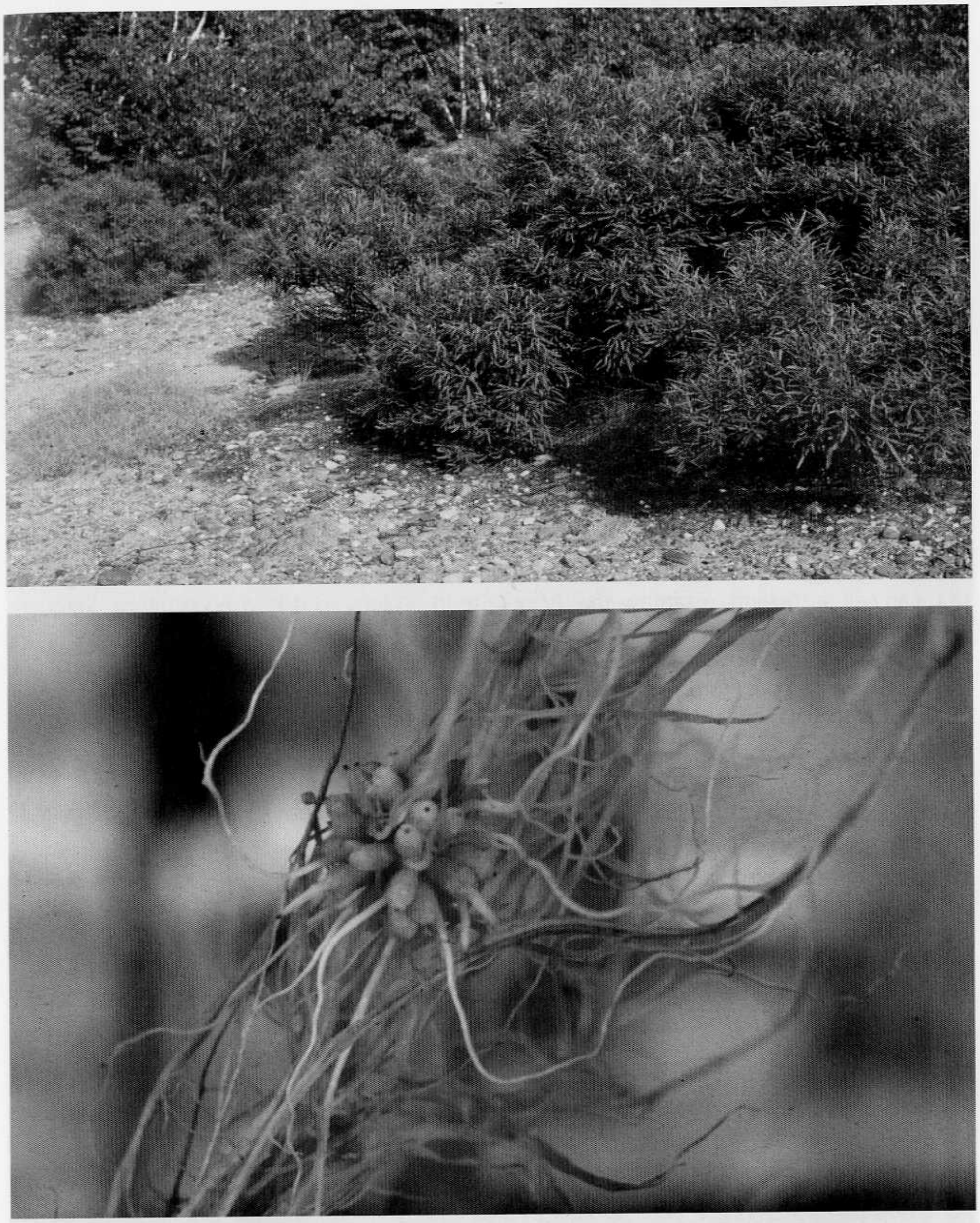

Figure 2.5 Top, the sweetfern, *Comptonia peregrina*, growing on a gravelly roadside bank in central Massachusetts; bottom, close-up view of a sweetfern root nodule growing in the laboratory. Photographs by Peter Del Tredici.

to my definition of this overused word, sustainable landscape plants are those that can tolerate the conditions that prevail on a given site, require minimal levels of maintenance in order to get established, and display a limited capacity to spread by seed into surrounding natural areas. In general, they are tolerant of a broad range of light, moisture, and nutrient conditions (Del Tredici 2001a: 10–18). Landscapes that are designed with such sustainable plants – including both native and introduced species – will not only be less costly to maintain over time, but also more adaptable to the unpredictable weather patterns and pathogen problems that clearly loom in the future. When it comes to selecting plants for re-vegetating disturbed sites, American designers have much to learn from their European counterparts, who have a long tradition of using cosmopolitan plant associations to create stable, naturalistic landscapes in a wide variety of habitats (Hitchmough and Dunnett 2004: 1–22).

For mining-reclamation projects, in particular, it is important to select trees and shrubs that have a strong capacity to produce new shoots either from their roots ("suckering"), as in the case of quaking aspen (*Populus tremuloides*), black locust (*Robinia pseudoacacia*), and gray dogwood (*Cornus racemosa*) (see Figure 2.6), or from the base of their trunks following traumatic injury ("coppicing"), as in the case of sweet birch (*Betula lenta*) (see Figure 2.7). In the former instance, the species are able to spread over time and cover large areas; in the latter, they are able to persist at stressful sites by resprouting after damage from predators or severe weather (Del Tredici 2001b: 121–40). Such disturbance-adapted, "pioneer" species are clearly the best choice for re-vegetating steep mining sites, in which the succession process starts with bare rock. In Table 2.1, I have summarized the life-history traits that, in general, preadapt woody plants for re-vegetating mine reclamation sites.

The fourth and final aspect of my strategic approach to reclamation requires an acknowledgment – early on in the design process – of the need for ongoing maintenance at all constructed landscapes, regardless of scale. All too often the concept of sustainability is misinterpreted to mean self-sustaining, a fantasy that is as false in ecology as it is in horticulture. Standard landscape maintenance practices – including irrigation, weeding, mulching, and replanting – are necessary to promote the successful establishment of any new planting, regardless of the theories it is based on. From the horticultural perspective, a truly sustainable landscape design is one that is in balance with the financial resources available to maintain it (Koningen 2004: 256–92).

Figure 2.6 Opposite, all of the stems in this clonal grove of quaking aspen, *Populus tremuloides*, in the Rocky Mountains of Colorado arise from a common root system; top, the black locust, *Robinia pseudoacacia*, reproducing from root suckers on a vacant lot in Boston; bottom, the gray dogwood, *Cornus racemosa*, spreading by root suckers along an abandoned roadway in Boston. Photographs by Peter Del Tredici.

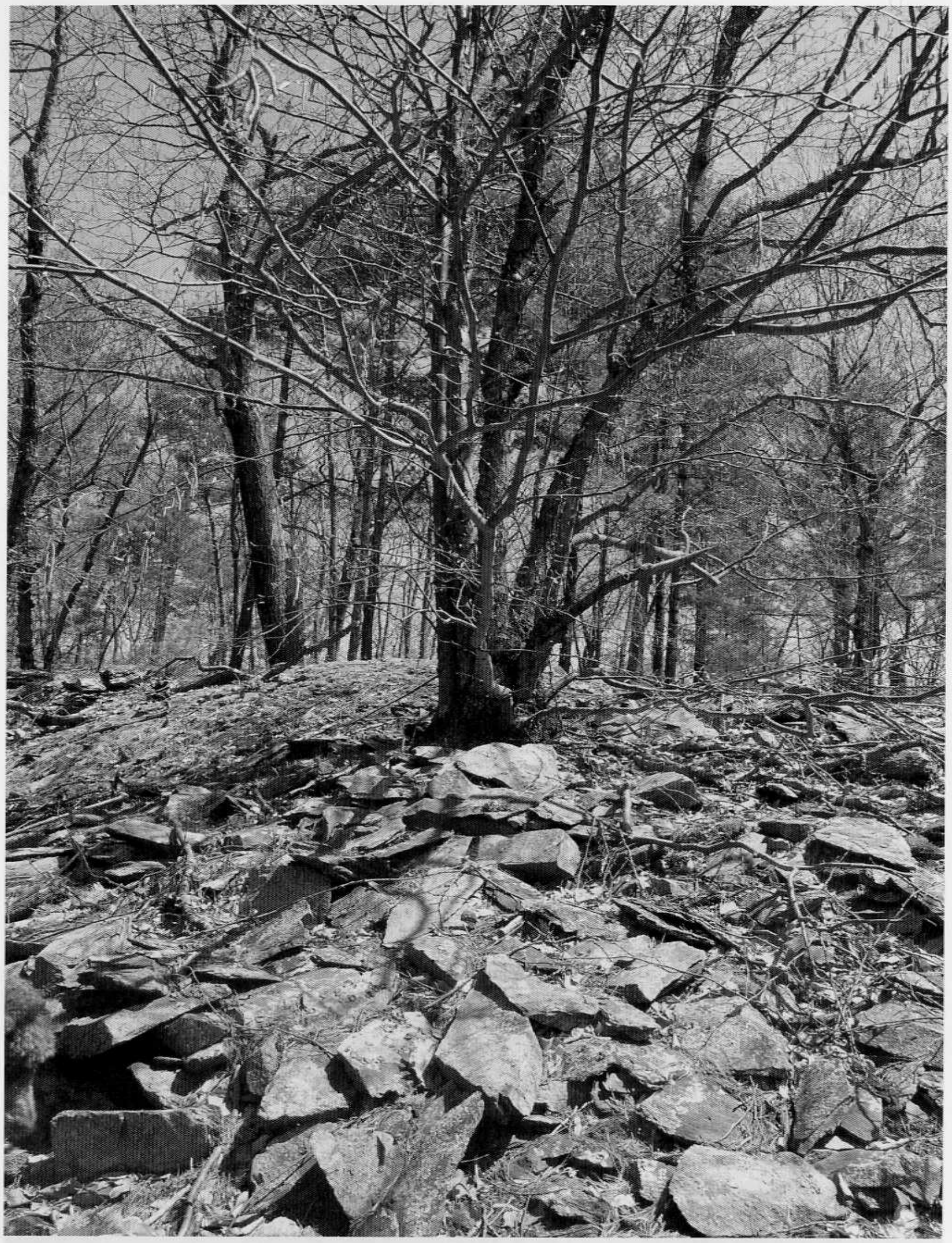

Figure 2.7 The black birch, *Betula lenta*, growing on a hundred-year-old pile of weathered slate slag, in the town of Harvard, Massachusetts. The tree displays a multi-stemmed growth form. Photograph by Peter Del Tredici.

Table 2.1 A summary of the basic life-history traits that preadapt some woody plants for growth on mine reclamation sites.

- germinate readily from seed
- be relatively fast growing
- be tolerant of extreme sun and wind exposure as well as high soil and air temperatures
- possess a strong capacity for vegetative regeneration from suckers, stump sprouts, rhizomes, or branch layers
- be able to grow in soils with high concentrations of heavy metals
- be able to grow in soils with low pHs
- be tolerant of drought induced by coarse textured or highly compacted soils
- on wet sites, be tolerant of saturated soils with low oxygen tensions and high concentrations of toxic compounds
- be able to form symbiotic relationships with a broad range of both ecto- and endomycorrhizae
- on low nutrient sites, be able to form symbiotic relationships with nitrogen-fixing bacteria

What would Olmsted do?

The ecological approach to mine-reclamation design that is outlined above requires changing the focus of the design process from its traditional emphasis on form (i.e. the species list) to an emphasis on ecosystem function (i.e. energy flows, water use, mineral cycling, and carbon sequestration). In practical terms, this translates into installing more, smaller, bare-root plants, as opposed to fewer, larger, ball-and-burlap or containerized plants, thereby allowing the microclimatic features of the site to determine which individuals live and which die. The designer's role is to develop the palette of plants to be used on the site and to determine the placement of those plants in relation to gradients of topography, aspect, soil type, and moisture.

The technique of over-planting small material requires abandoning the age-old practice of assigning individual plants to fixed locations in a planting plan and replacing it with mixed plantings of trees, shrubs, and herbaceous perennials. Adopting this change in planting strategy is difficult for some landscape architects, because it means giving up a measure of control over the planting design to the plants themselves. But one can take heart in the fact that the great Frederick Law Olmsted always over-planted his public parks, with the intention that they would later be thinned out. In his plan for the park at Niagara Falls, written in 1889, he articulated a philosophy that is directly applicable to today's large-scale reclamation projects:

> They [the plantings] are to be thinned out gradually as they come to interlock, until, at length, not more than one-third of the original number will remain, and these, because the less promising will have constantly been selected for removal with little regard to evenness of spacing, will be those of the most vigorous constitution, those with the greatest capabilities of growth, and those with the greatest power of resistance to attacks of storms, ice, disease and vermin. Individual tree beauty is to be but little regarded, but all consideration to be given to beauty and effectiveness of groups, passages, and masses of foliage.
>
> (Olmsted 1928: 370)

Olmsted's instructions make it clear that he viewed landscape design as a dynamic rather than a static process. Sustainability, if the term has any meaning at all, is about form following function and about allowing landscapes the time they need to develop complexity and character through long-term interactions with their environment. It is not about moving big trees around like chess pieces to create instant, climax-forest effects. Landscape architects can embrace this concept of sustainability by making ecological functionality and environmental adaptability primary design goals.

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