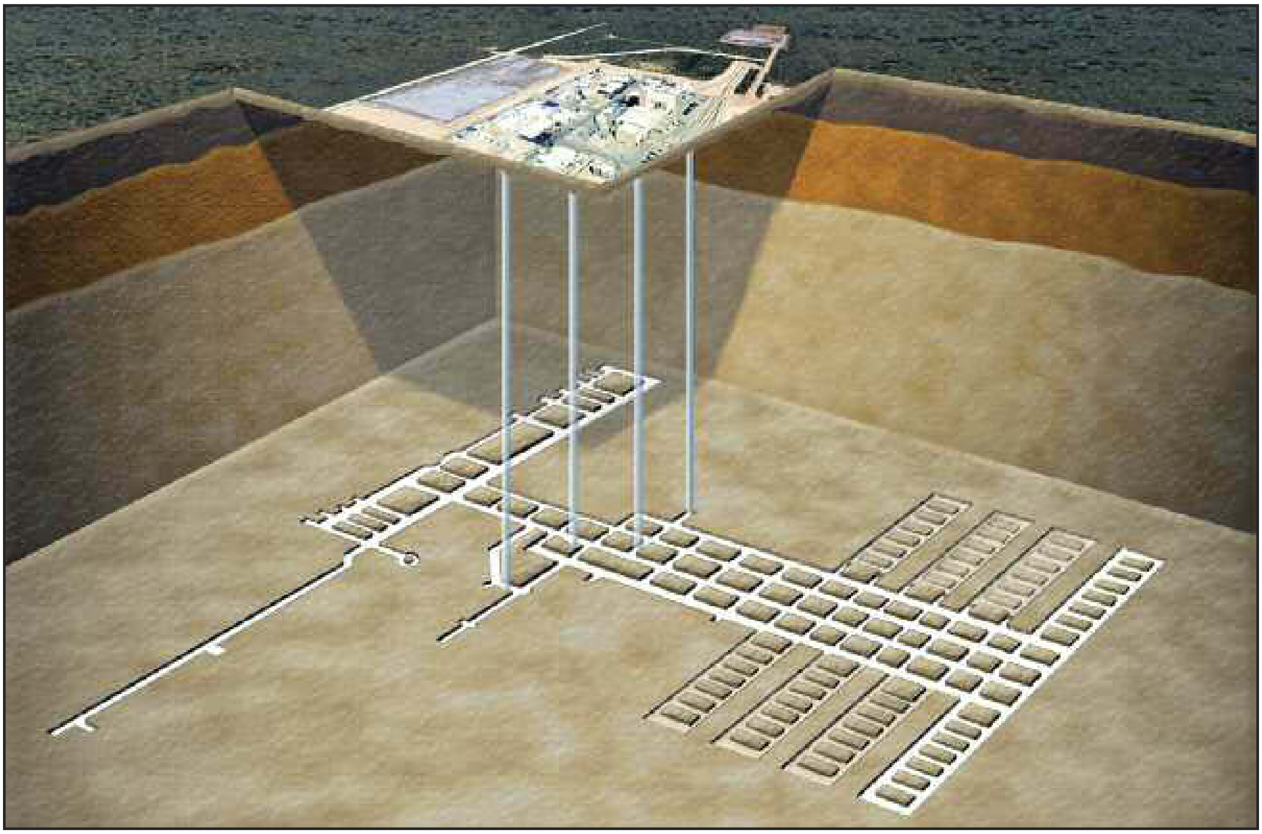
The Salt of the Earth



25 Years of Experience in WIPP Underground Operations

More than 25 years of underground experience and a decade of disposal operations at WIPP have proven that salt is an excellent medium for a deep nuclear waste repository.

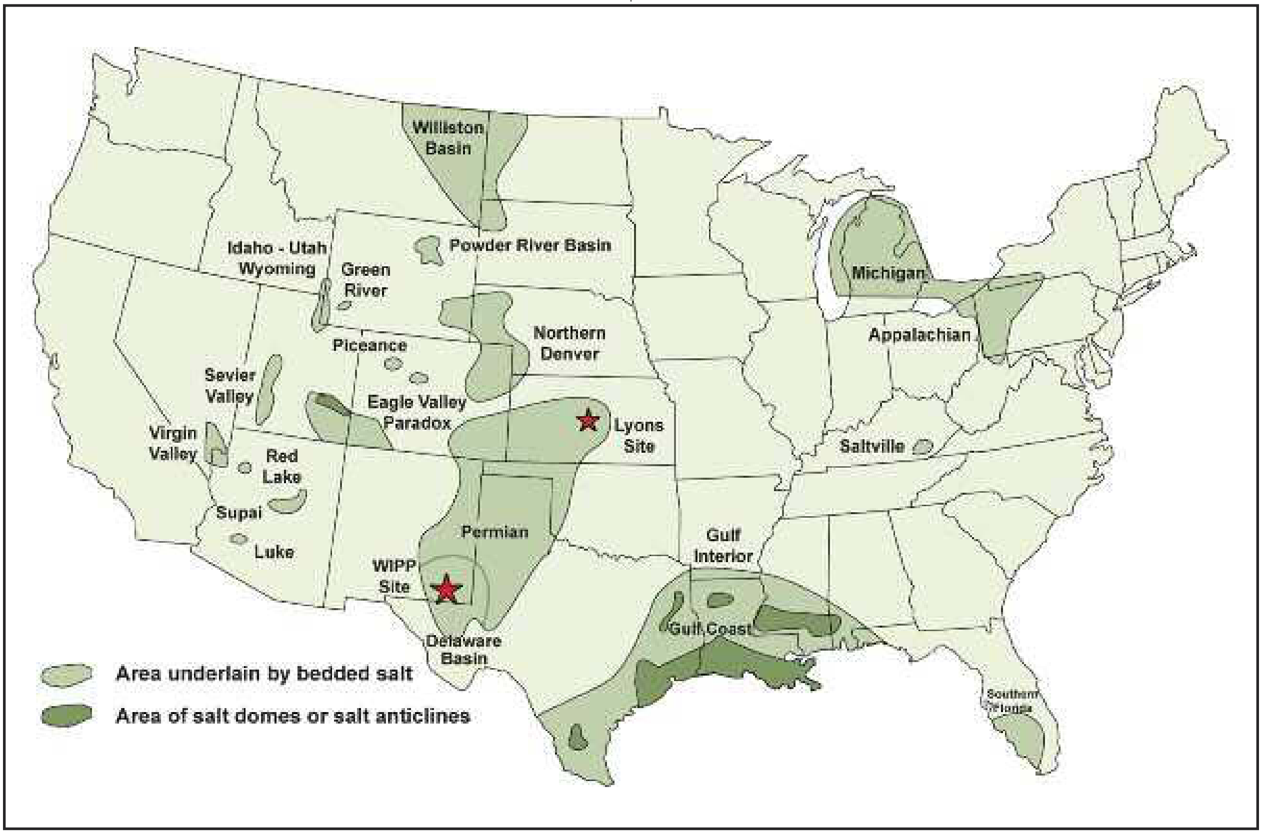
By John D. Vandekraats and Stanley J. Patchet

More than 25 years of underground experience and a decade of disposal operations at the U.S. Department of Energy's Waste Isolation Pilot Plant (WIPP) have proven that salt is an excellent medium for a deep nuclear waste repository. The WIPP underground repository continues to be stable and to comply with the original objectives and requirements for long-term containment. Now is a good time to examine how the facility came about and what knowledge has been gained.

Choosing the Right Site

In 1957, the National Academy of Sciences issued a report identifying deep geologic isolation as a desirable mode for disposal of radioactive waste. The report also

Above: *Three-dimensional cutaway of the WIPP repository underground layout, with disposal panels to the south (bottom), experimental areas to the north, and overlying rock stratigraphy above.*



Deep geological salt deposits in the United States. The Delaware subbasin of the Permian Basin is the thickest contiguous deposit at a depth that balances closure rates with safe disposal operations.

identified salt, with large deposits existing worldwide, as the preferred host rock. The primary advantage of a salt repository is the ability of the salt to creep under overburden pressure and encapsulate the disposed waste. Further advantages include the comparative ease of mining, the absence of flowing water, and a high thermal conductivity. A salt repository is, therefore, suitable for all categories of radioactive waste, including those that generate significant heat.

In the vicinity of the WIPP site, a thick, bedded salt deposit extends over thousands of square miles, where the salt sequence is more than a half-mile thick. It was laid down at the end of the Permian era, when the ancient supercontinent, Pangea, was just beginning to break up. Repeated evaporation of a broad tidal flat as the local crust sank produced an enormous evaporite deposit of seawater minerals. This salt has been preserved for more than 250 million years and is expected to remain stable for millions of years into the future. Local and regional geology is straightforward, well known, and understood because of the presence of potash mining operations and petroleum exploration and extraction. There are no indications of tectonic activity that might disturb the repository. Almost 80 years of industrial

Roof bolting allows rooms to be maintained open and safe for as long as needed to complete emplacement operations.

A newly ready disposal room in Panel 3 showing width and height before significant closure begins. Note the comparative lack of roof bolts.

operations in the Carlsbad Potash Basin have confirmed the confidence in salt properties and behavior and provided an available and capable labor pool as well.

Confirmation of Safety— Proving the WIPP

The earliest surface-based confirmation work confirmed assumptions and predictions based on near-site experience with potash mining, petroleum exploration, and even an early-1960s science project that included a nuclear detonation. Subsequent detailed underground in-situ characterization was performed as shafts and underground drifts were mined in the mid-1980s. A site and preliminary design validation phase confirmed the suitability of the site and its design.

During this phase the main drifts, a simulated disposal area, and experimental and test areas were excavated. Geotechnical monitoring began during this time and has continued ever since. The size and configuration of planned waste disposal rooms and panels were validated. Researchers conducted experiments and tests to monitor the mechanical behavior of the salt. Some included simulated heat-generating waste, others confirmed hydrologic properties demonstrating that WIPP salt is essentially dry and impermeable, and still others established the ability to plug and seal the repository.

The results of the validation activities confirmed initial expectations. WIPP salt beds are continuous and relatively level. Mining is relatively quick, easy, and economical. It can be controlled such that the openings can be laid out and mined precisely without explosives, using continuous-mining machines. Conditions are clean and dry, and any dust generated is a nonhazardous, minor nuisance material—common salt. Geotechnical data collected validated the expectation that the openings creep and close over time, albeit at rates somewhat higher than originally anticipated. The data were found to be useful as a tool in understanding ground conditions and in determining when to install any ground support needed to preserve opening integrity and ensure personnel safety. The principal method used to provide ground support is to install rock bolts in the roof and walls of openings. Like excavation using continuous miners, mechanized rock bolting in salt is relatively quick and easy.

Operational Experience to Date

After more than 25 years, the WIPP underground repository continues to be stable and comply with the original objectives and requirements. WIPP's underground layout is essentially unchanged since original design. Excavation performance has met, and continues to meet, design requirements. The expected life of the project has increased through the years due to startup delays and modified priorities. Even with the extension there are no reasons to believe that with continued maintenance the repository will not continue to perform adequately and to meet any desired life extensions.

Geotechnical monitoring continues in all open areas, not only to confirm long-term performance, but also to ensure operational safety. This monitoring includes subsidence monitoring on the surface and geomechanical monitoring (e.g., convergence monitoring in the openings and dilation of the roof) in the underground at literally hundreds of locations, visual observations including mapping and tracking fractures that develop, and borehole observations. Particular attention is paid to those areas where local geological factors (e.g., localized bedding features) have an impact on ground conditions.

WIPP proudly displays the New Mexico Mine Operator of the Year award.

Where openings are comparatively large and wide, convergence rates are typically higher than in openings of smaller cross section. Because waste disposal rooms are among the largest and widest at 13 feet high, 33 ft wide, and 300 ft long, it is not unusual to have as much as a foot of convergence in the first year after excavation when the ground response is highest and 3 to 5 inches per year thereafter. Although this convergence is desired when it comes to long-term performance of a repository in entombing the waste, it is a factor that must be taken into account during the operational phase. We found that if the rooms were not used in a timely manner, this convergence could accumulate to the extent that the disposal room height was not sufficient to efficiently perform waste handling operations. This lesson was learned early when delays in permitting left the first waste disposal panel ready and waiting for years. Before emplacement operations could begin in these areas, they were renovated by excavating the floor and ribs as necessary to reestablish the necessary operational clearances.

Today, with the repository now receiving waste on a regular basis, disposal panels are prepared "just in time"—that is, the panel excavation, outfitting, and regulatory certification are completed a few months before the waste disposal schedule requires them to be available. A panel consisting of seven waste disposal rooms is mined and outfitted with ventilation controls, lights, and communications while the one previously completed is being filled with waste. In addition, rooms and drifts in the waste panels are now mined to a height and width that takes into account the expected convergence. Just-in-time mining also levels the workload of both personnel and equipment, making it an efficient work method. In addition, this mining plan provides younger openings, which are more stable and hence require less maintenance during the disposal cycle. This eliminates potential conflicts with the waste disposal operations.

Some of the main access entries are now more than 25 years old. These are life-of-facility openings; consequently, they receive regular maintenance and renovation when necessary. Renovation is relatively easy and can be done in a variety of ways. Most commonly the floor is releveled by watering and dragging mined salt on the roadway, and occasionally the walls are trimmed. As the roof creeps and expands, roof bolts may fail. They are replaced as necessary to maintain ground support. More extensive renovation consists of using a continuous miner to excavate the floor, reestablish operating clearance, or mine up into the roof and rebolt, if it becomes too fractured to support efficiently.

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Large equipment underground, such as this facility cask shielding remote-handled waste in canisters, requires wide, tall openings underground.

Knowledge Gained during WIPP's Lifetime

Although safety is emphasized in the mining industry, WIPP extends this in the underground repository to the levels expected of a nuclear facility. Safety is emphasized not only for personnel, but also for the facility and the public through both occupational rules and nuclear process rules. From the standpoint of mining safety, WIPP has been awarded Mine Operator of the Year honors for 22 consecutive years by the New Mexico Mining Association. This is based on WIPP incident and injury rates ranking far below the national averages for operating mines. The lessons learned are to set clear, safe work expectations and to train operators on the best methods to achieve them. The WIPP safety culture emphasizes clear expectations, good communications, operator feedback, recognition of good performance, and continuous improvement.

Another lesson learned is the need to consider and, whenever possible, plan for additional requirements and changing priorities. One case in point at the WIPP is salt hoisting capacity. After several years of disposal operations, the DOE wished to accelerate waste disposal beyond the designed single-shift waste disposal throughput rate, and this change required a higher panel development rate. The panel completion rate could be increased simply by hiring more employees and running additional shifts. However, salt could not be hoisted at the higher excavation rate on a single shift without very expensive and time-consuming alterations to the salt shaft and hoist.

Workers solved the problem by performing all excavation on the early shift, stockpiling any excess salt underground, then hoisting it to the surface during the late shift. This process involves double handling of a portion of the mined salt and incurs some additional handling cost, but this additional cost was justified by faster removal of waste from generator sites. The lesson to be drawn from this experience is to design a repository to be robust and capable of adaptation should priorities change.

Given that convergence rates and the potential for opening deterioration are somewhat higher for larger openings, at WIPP it is best if opening sizes can be minimized. The size of waste handling equipment may have little impact if used on the surface. However, large pieces of equipment such as the cask transfer car for the remote-handled waste facility and the large forklifts require large underground openings in which to operate. The lesson learned is to design large pieces of waste handling equipment to minimize their operating envelope and, therefore, their potential impact on the opening performance.

Experience has shown the need to identify single-point failures and to mitigate them in the design stage. WIPP managers procured additional equipment and spare parts and added them to inventories to address identified single-point failure situations. However, waste transportation from the surface to the disposal panels is possible only via the waste shaft and the East 140 drift. Normally, this is not a problem, but when unplanned or major maintenance is required, no alternative exists to continue waste disposal operations in the underground while performing the maintenance work. WIPP is currently pursuing the possibility of modifying another main drift to serve as a waste transport route, so maintenance can be performed while continuing to transport and emplace waste.

A lesson learned from the mining industry is to consider the value of retreat emplacement of waste. In many mining operations a retreat sequence is used to extract the ore. Typically, access drifts or mains are excavated to the ore body edge, end of a panel, or to the lease boundary. The maximum amount of ore may be mined at the extremity and mining progresses by "retreating" back toward the main access. This is advantageous for several reasons. Typically, the mining face, where the mining is taking place, is immediately adjacent to a solid barrier or pillar, and stability is best there. The ore can be taken back safely through mains in the relatively solid pillar and transported from the mine. The ground that has been mined need not be reentered, accessed, or maintained further. This ensures safety of personnel and minimizes maintenance requirements.

The WIPP employs this retreat sequence in the waste disposal process. In each disposal panel, waste is emplaced in the room farthest from the mains first, and when it is filled, it is closed to access and removed from the ventilation system. Then the process is repeated in the adjacent room. This sequence of retreating out of a panel continues until the panel is filled. Although the retreat process is used in panels, the WIPP long-term plan requires the panels be filled in a rotational sequence around the main entries, which are then filled on retreat. This has some theoretical advantages, but these are far outweighed by challenging operational ventilation configurations and the additional maintenance and renovation work required by the existing sequence. A lesson learned might be that if the original design had allowed for the panels located farthest from the shafts to be filled first and their mains to be subsequently filled, costs associated with long-term maintenance of the aging mains may have been substantially reduced over the life of the project.

The final lesson learned is simply the conclusion that the WIPP repository continues to be stable and to comply with the original objectives and requirements. Salt has proven itself as an excellent medium for permanent disposal of nuclear waste. The WIPP continues its mission today and will continue operations to safely and compliantly dispose of the nation's defense-related transuranic waste. ■

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