DOLBY FAMILY VENTURES

# Understanding the Copper Market – Innovation

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**Summary of Part 3.** Part 3 focuses on how certain venture-style innovations, if successful, will affect the supply/demand equation, viewed through the lens of four portfolio companies. We discuss technology adoption at brownfield sites, the power-law and widening opportunity for upstarts in greenfield exploration, and summarize why our portfolio companies have taken their respective market positions, as well as how, if successful, they will matter to the industry. While our perspectives on what makes for compelling venture opportunities in this space are, by nature, embedded in (continued) investment decisions, we do not go into further detail here. For a deeper discussion around current and go-forward hypotheses, and how market dynamics have shaped them, please reach out to the author.

- **Transition Metal Solutions** develops site-specific chemical additives that improve existing leach operations and enable economic processing of low-grade mineralogies currently considered waste.
- **Esper Satellite Imagery** accelerates the earliest stages of greenfield exploration with a satellite-based sensor that delivers affordable, high-resolution hyperspectral data services to (junior) miners and their technology vendors.
- **Vorticity** leverages GPUs and custom-built software to accelerate computationally expensive geophysical methods, enabling efficient identification of copper porphyry deposits at depth.
- **Kuprion** manufactures a novel nanocopper formulation that solves critical thermal and electrical challenges faced by those designing or building AI and high-power compute solutions, showing why copper's properties are sought after in many current and future applications.

**Opportunity and Technology Adoption at Brownfield Sites.** Innovation can deliver value at existing mine sites in two primary ways: (i) by reducing cash costs for existing operations; and/or (ii) by profitably increasing production volumes. In Part 2, we showed that productivity gains have generally ceased, implying that miners need new tools to keep cash costs low. We also examined how the deployment of solvent extraction-electrowinning unlocked significant capacity at brownfield sites in the US, converting low-grade uneconomical ores into those profitable to produce. This reclassification of resources into reserves remains consequential today. From 2001-2014, "[n]early 80% of the industry's gross new reserves . . . came not from new discoveries, nor from finding new copper zones within, alongside, or beneath existing deposits. Instead, almost all of these reserve additions came from re-classifying what had been considered waste rock into minable ore" (Goehring & Rozencwajg, 2021). Though this was primarily attributed to elevated prices during the period, the inverse (i.e., reducing cash costs) yields the same net result. Considering these factors, we have come to view unlocking the full potential of these sites, through both avenues initially mentioned, as an attractive value proposition for venture capital funding.

Over the last few years, Dolby Family Ventures has reviewed many brownfield-focused technologies. The ones we find most attractive share a few common traits. First, their efficacy is maintained at the scale required for these operations (e.g., contending with daily ore throughputs of up to hundreds of kilotonnes). Second, they can easily manage the heterogeneity of ores at and across different mine sites. Third, they do not require an entirely new workflow or flowsheet but fit into existing processes seamlessly, and because of that, have an appropriate go-to-market strategy. This last criterion warrants additional context, given the prevailing narrative that the mining industry is reluctant to deploy innovative solutions. Technology adoption behavior is driven by the structure of a customer's business, which, for miners, entails high initial capital outlays and the need to maximize uptime to achieve necessary returns. When a company decides to develop and bring a project online, it should be able to achieve projected returns if the base underwriting case materializes, absent the need to deploy any additional innovation. Thus, new technologies that risk disrupting cash flows are carefully considered before adoption. In fact, the sector has a supplier-dominated innovation profile for that reason. Trusted vendors incorporate ready-made innovations, often derisked elsewhere, into existing equipment, processes, and/or flowsheets, helping miners avoid that risk (Sanchez & Hartlieb, 2020). It is perhaps most evident today in the autonomous haulage systems and drilling rigs provided by the likes of Komatsu, Caterpillar, Epiroc, and Sandvik. Our view is that the scalability, breadth, and method of delivery greatly influence whether an innovation has a chance at having an outsized impact on this specific market. These traits are among the primary reasons we built conviction in Transition Metal Solutions ("Transition").

**Transition Metal Solutions (Invested Q2 2024).** Transition's site-specific additives improve existing leach operations and enable the economic processing of low-grade mineralogies currently considered waste. They do this with off-the-shelf chemical compounds

that, when added to a leach solution, unlock the latent potential of indigenous microbial communities that already drive copper production. Their technology platform abstracts away the (microbial) heterogeneity seen across space and time at a site, delivering custom-tailored leach enhancers to specific heaps or stockpiles. Having a distinct mechanism, the technology complements existing physicochemical process optimization developed and deployed by expert metallurgists and mining engineers. This adds a layer of microbial ecosystem optimization that can be consequential to successful leach cycles. Importantly, their end-to-end process runs at a speed that fits into existing leach preparation workflows and requires no additional permitting or infrastructure.

Informed by their own direct experience with copper mines, the team built the technology and operational approach around the natural constraints any innovation like this will face upon deployment. As such, their strategy is built around the three tenets previously discussed: scalability, breadth, and viability of the delivery method. In a time when the industry is actively searching for improved leaching solutions to unlock value across existing portfolios (see FCX's Leach Initiative, BHP's Full SaL, RIO's Nuton, ANTO's Cuprochlor-T), ones that are easy to transfer from site to site, like Transition's, can shape how comfortable customers can get adopting the new technology, ultimately influencing how impactful the solution could be across the industry writ large. If Transition continues to execute and the scaled-up readout is as favorable as projected, the solution could be an important vector for expanding miners' margins and helping the industry unlock the value of low-grade sulfide ores, not too dissimilar to how solvent extraction-electrowinning enabled the production of low-grade oxides in the 20th century.

*Note: The technology is also applicable at greenfield sites. We view brownfield deployments, not only as an immediate opportunity, but also as a way to offer new mine developments commercial proof points of efficacy.*

**The Opportunity in Greenfield Exploration.** Despite the challenges associated with greenfield exploration, it remains a critical part of the future supply base and a meaningful opportunity for venture capital. The reduction of grassroots budgets by the majors, alongside juniors diverting funds away from exploration to development, creates space for new entrants. However, investing in greenfield exploration or junior mining carries significant risk. The value capture exhibits a power-law distribution, one with which venture capital is familiar. In the Doggett and Leveille analysis we discussed in Part 2, 4 out of the 100 most significant mines brought to production between 1989-2008 were estimated to account for ~75% of total returns, while the median trailed the cost of capital. Commenting on the difficulty of the business, David Humphreys, former Chief Economist at Rio Tinto and Norilsk Nickel, reminded us that "nothing beats finding a new, big orebody." We agree. The risk-return profile is well understood by us and others in the venture ecosystem. That is one of the reasons we believe venture capital is well suited to support greenfield exploration efforts for the industry. As a result, we have two portfolio companies operating in this part of the value chain – Esper Satellite Imagery ("Esper") and Vorticity – each with varying degrees of exposure to the aforementioned risk-return profile.

**Esper (Invested Q3 2023)** pairs a proprietary satellite-based hyperspectral sensor with an AI model trained on geologic data to deliver meter-scale mineral mapping. This approach, which uses surface reflectance to infer chemical composition and identify areas of interest, has long been used in exploration; however, it has historically been constrained by the challenge of translating raw spectra into reliable geological interpretations. "The complex mixtures of minerals and the presence of spectrally similar phases often complicate classification algorithms and classification accuracy. . . . These factors contribute to conflicts between remote sensing data and ground-truth geological observations" (He, 2025). A small cohort of start-ups, including Esper, looks to leverage advances in compute to unlock the full value of this technology. Esper aims to do so by combining higher-resolution sensors with new AI models trained on geochemical and geophysical data. (Junior) miners and their technology vendors already use hyperspectral data collected in a handful of ways, including by satellite and aerial means, as inputs for modeling and decision-making. For those leveraging publicly available data, Esper will have to prove to these customers that its solution not only consistently delivers ground-truth geological observations but is also markedly better than their current data sources to warrant material data service payments. If successful, they have the chance to be a valuable efficiency driver for the billions spent every year on copper (and other mineral) exploration, allowing miners to reach drill targets faster and more cheaply.

**Vorticity (Invested Q1 2022)** is a scientific computing company with a business unit focused on uncovering copper porphyries at depth under sedimentary cover as a project developer. Today, shallow porphyry systems account for most of global copper production, and porphyry deposits remain a primary focus of exploration and development for the industry, largely because they offer the highest risk-adjusted return profile of any deposit type. A recent paper published in SEG Discovery makes the case that exploration efforts should be focused on porphyry orebodies at depth, even in areas with mature exploration histories, like the Southwest US, noting that an "area's discovery potential may be enhanced if artificial intelligence and machine learning are able to access and process much of the extraordinary amount of data from porphyry Cu deposits and exploration that has been accumulated

in [mature regions since the early part of the 20th century]" (Wood & Schodde, 2026). While the authors make a strong argument for why large miners are best positioned to execute on this[1], Vorticity believes that deploying novel tools can help shift expected value and make the project development model work better for these opportunities. The company utilizes modern GPUs to process high-resolution geophysical data. This hardware acceleration enables more robust 3D geophysical inversions and the efficient generation of complex multiparameter, multidimensional subsurface models. The expanded computing power allows for advanced model-space exploration, running families of inversions to quantify uncertainty and map entire mineral systems at a continental scale rather than just isolated targets. It then deploys AI to interpret these complex subsurface models to make discoveries. By integrating machine learning with these physics-based models, they can rapidly evaluate large datasets to pinpoint and rank high-confidence exploration zones that human analysis alone might miss. Proving the viability of this approach, Vorticity has already shown recent success in making discoveries. Moving forward, the value that can be created for the market and business, if a high-quality deposit is delivered, goes without saying.

**Exploiting the Character Traits of Copper to Drive Demand, Kuprion (Invested Q4 2018; Acquired by ESI Q2 2023).** In Part 1, we showed that copper's unique mix of functional traits translates to widespread and diverse end-use applications. We end the series by looking at how Kuprion leverages those properties to create new demand in applications critical to the future global economy, highlighting the idea that there are known and unknown end-uses for copper yet to be unlocked that may impact the supply/demand balance. Demand for compute has accelerated rapidly since the launch of ChatGPT, and the thermal loads and power densities required for AI and high-performance computing have pushed existing materials to their limits. Kuprion's ActiveCopper solves that with its superior thermal and electrical conductivity, and widespread material compatibility. Its properties also create additional degrees of freedom for new architectures, advanced packaging, and other ways currently being used to scale compute in lieu of Moore's Law. Developed over nearly a decade at Lockheed Martin, ActiveCopper is a drop-in-ready nanoformulation that unlocks the use of bulk copper throughout electronic interconnect systems. Kuprion's solution has widespread applicability (e.g., antimicrobial properties make it effective for wound care), but has been specifically highlighted by its parent company, Element Solutions, for its ability to accelerate corporate growth in AI. There are three primary emerging pain points it is currently addressing. First, it improves power density in printed circuit boards ("PCBs") by replacing thin PCB traces with highly conductive power trenches, enabling high-current power delivery for AI GPUs. Second, its tunable coefficient of thermal expansion eliminates the mismatch of expansion behavior between copper interconnects and the advanced glass packaging substrates, or any substrate for that matter, the industry is targeting for high-performance computing. Third, it improves the reliability of i) PCBs subjected to extreme heat loads in high-power applications and ii) systems subjected to high-duty cycle AI inference workloads. Similar to how IBM's dual-damascene process enabled the use of copper interconnects in place of increasingly problematic aluminum in the 1990s, Kuprion's nanoformulation addresses similar application-based limitations (e.g., copper oxidation), allowing the semiconductor industry to leverage the performance advantages it has long known copper would provide across the entire interconnect system. As electrification, decarbonization, and AI continue to penetrate the global economy, we would expect more instances in which the need to drive performance or eliminate a bottleneck can only be met by specific metals/materials, such as copper. That need will create new demand centers for copper, thereby keeping pressure on supply.

**Conclusion.** Across this series, we have argued that copper pairs the most durable demand profile among critical materials with a supply base that cannot easily respond, and that the resulting gap rewards innovation. This creates an opportunity for venture capital to support the industry. Dolby Family Ventures remains focused on partnering with teams addressing problems across the value chain of the most consequential commodity for our electrified and decarbonized future. If you are building a business in this market, want to connect about the series at greater depth, or would like to discuss other investment hypotheses and areas, please reach out to the author at *usua@dolbyventures.com*.

[1] A recent study by Castillo & Roa (2026) also implies that those with the balance sheets that enable persistent investments over the long horizons of exploration (i.e., large miners) benefit from cumulative learning and are advantaged.