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THE PROBLEMS WITH COPPER SUPPLY

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"I have switched from being a structural copper bear to a structural copper bull." Leigh Goehring, Barron's Commodity column May 2001.

Copper has emerged as a leader in this commodity bull market. We are strong believers that copper prices are heading significantly higher. After bottoming at $1.95 per pound in early 2016, copper prices have more than doubled. Copper equities (as measured by the COPX ETF) have done even better, rallying over 200% — more than twice the increase of the S&P 500.

The previous copper bull market took place between 2001 and 2011 and saw prices rise seven-fold: from $0.60 to $4.62 per pound. As shown in the *Barron's* quote above, we wholeheartedly embraced that copper bull market and maintained sizable exposure throughout the rally. The fundamentals today are even more bullish. We would not be surprised to see copper prices again advance a minimum of seven-fold before this bull market is over. Using $1.95 as our starting point, we expect copper prices to potentially peak near $15 per pound by the latter part of this decade.

In past letters we focused heavily on the various sources of copper demand and how strong they would be: how Chinese demand growth would continue to exceed expectations; how India would emerge as an important new source of consumption; and how the desire to build out the renewable energy grid would introduce a whole new source of demand. This last point is especially important: while copper is now often referred to as a "green metal," few analysts understood the connection between copper and renewable energy when we first wrote about it in 2016.

In this essay, we are shifting our focus from copper demand to supply. Our models strongly suggest copper mine supply growth will grind to a halt this decade. The number of new world-class discoveries coming online will decline substantially and depletion problems at existing mines will accelerate. Also, geological constraints surrounding copper porphyry deposits, a subject few analysts and investors understand, will contribute to the problems.

"STAGNATING COPPER MINE SUPPLY, ALREADY COLLIDING WITH STRONG DEMAND, WILL PUSH COPPER PRICES FAR HIGHER THAN ANYONE EXPECTS."

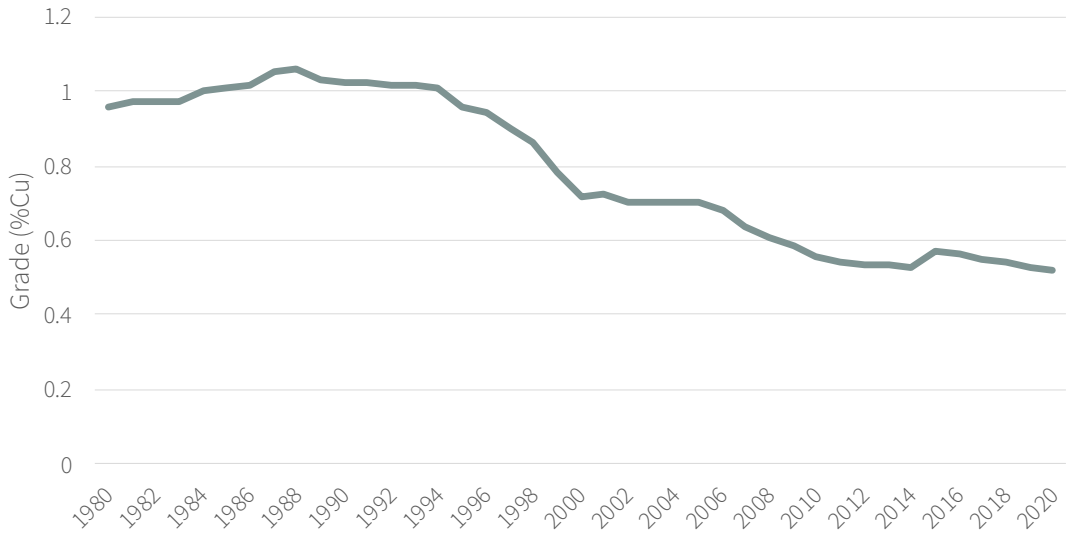
Stagnating copper mine supply, already colliding with strong demand, will push copper prices far higher than anyone expects.

Significant shifts began affecting global copper supply trends more than 15 years ago. The copper industry in 2005 began to quietly suffer from depletion problems. What depletion is and how it is measured is an extremely complex subject. Academics, engineers, and investors vigorously debate what exactly constitutes depletion and how it should be measured. In broad terms, mining causes two types of mineral depletion: a decrease in the quantity of the initial mineral reserve and a decline in the quality of the remaining mineral reserves. Here, we focus on the declining quality of copper ore reserves, what that does to the "head grade" (that is, the quality of the ore being mined), and its impact on future copper mine supply. As you will see, both ore reserves and quality of ore being mined are in pronounced declines.

Prior to 2005, few investors paid any attention to these related issues of depletion. The reason was simple: the average reserve grade and head grade of the copper industry had been trending upwards since the early 1980s. An extremely large number of new high-grade copper mines commenced production, starting in the late 1980s. State control of the Chilean copper industry was relaxed in the mid-1970s, leading to an explosion in exploration spending. Solvent-extraction electro-winnowing (SX/EW) allowed for the processing of oxide copper deposits (previously not possible) in the early 1980s. And there was the discovery and development of the massive, high-grade Grasberg copper-gold project in Indonesia. By the late 1980s, the world was about to be flooded with new copper supply — all of it mined from new high-grade deposits.

However, by the late 1990s new trends were beginning to take hold. The introduction of new large-scale copper mines slowed dramatically while depletion in the existing, aging mine base slowly began to accelerate. In the summer of 2005, I had dinner with Richard Adkerson, CEO of Freeport-McMoRan, now the world's largest copper company. He told me how bullish he was regarding copper prices. At the time, copper had just reached $1.50 per pound and investors had turned universally bearish, believing new supply would soon overwhelm demand. Mr. Adkerson explained that investors did not appreciate the depletion problem quickly taking hold and that copper mine supply growth would disappoint versus expectations. He added that the copper market would remain in deficit and copper prices would continue to move much higher. These were all great calls on Mr. Akderson's part.

FIGURE 1 Average Grade of Copper Remaining Reserve



Source: Wood Mackenzie, Bernstein, G&R models.

"MR. ADKERSON'S COMMENTS MADE A BIG IMPRESSION ON ME, SO IN THE SUMMER OF 2005 WE DECIDED TO UNDERTAKE A LARGE-SCALE RESEARCH PROJECT ON THE SUBJECT OF COPPER MINE DEPLETION."

Mr. Adkerson's comments made a big impression on me, so in the summer of 2005 we decided to undertake a large-scale research project on the subject of copper mine depletion. Prior to 2005, as far as we knew, no one had yet studied the nascent subject of depletion as it pertained to copper mining. We eventually modelled 115 mines representing 80% of global mine supply outside of China and what we found confirmed what Richard Adkerson had told me: after years of steadily rising, copper head grades had started to quietly decline. Incorporating all this new data into our copper mine supply model, we predicted the head grade drop would accelerate and wrote in our 2005 investor letter that mine supply would be "insufficient to close the structural gap between supply and demand [and that] copper prices must remain high."

FIGURE 2 Copper Price

Source: Wood Mackenzie, Bernstein, G&R models.

Our analysis was correct. In previous high copper price cycles (1988 and 1994 for example), an immediate supply response almost always occurred. The reason: miners still had high-grade copper-rich zones that could be easily accessed and mined. However, by 2005, the creeping depletion problem made short-term supply responses harder to achieve because easily accessible high-grade zones had been mined long ago. Instead of retreating back below $1.00 as everyone expected, copper prices more than doubled over the next six months reaching a then-record $4.10 per pound — more than twice the previous all-time high of $1.65. The bull market lasted another five years before finally peaking at $4.65 per pound in 2011.

High prices eventually did bring about a significant mine supply response but it took over 5 years. Between 2005 and 2010 copper mine supply grew annually by only 1.4%. However, by 2010 copper mine supply was set to grow strongly. In the Democratic Republic of Congo the massive Tenke Fungurume deposit was developed and the Katanga mine was expanded. In Zambia, the huge Sentinel copper market came online in 2015. In Peru, the giant Toquepala mine was expanded while new massive greenfield mines Las Bambas, Toromocho, and Constancia all commenced production. In Kazakhstan, the large Atkogay copper mine came online in 2016. In total, mine production grew 27% between 2010 and 2016 — almost three times as fast as between 2004 and 2010. The final surge in mine supply growth coincided with copper's low of $1.95 in 2016. Since 2016, copper mine supply has hardly grown, which brings us up to today.

The question is what will happen to copper supply as we progress through this decade? Our research strongly suggests that supply growth, which has been minimal since 2016, will continue to disappoint.

Back in 2014, as the copper bear market dragged on, we decided to update and expand our original 2005 copper mine supply study. At the time, copper demand had remained strong, but supply was growing rapidly. We wanted to create a "roadmap" telling us when copper mine supply might slow. Slowing copper supply would give us the signal to aggressively re-establish our copper related investments. In that project, we expanded our research to include reserve data as well as production trends. Our model included 24 copper producers going back to 2001 representing over 65% of global production outside of China.

At first, the data perplexed us. Our previous study suggested the industry faced a serious depletion problem. Even after all the new mine development, the industry's head grade was still 30% lower in 2015 than in 2001 and the capital cost per tonne of annual production had surged four-fold from $20,000 to $80,000 — both classic signs of depletion. On the other hand, the industry was adding new reserves very easily — not normally an indication of depletion problems. Between 2001 and 2014 the companies in our index replaced nearly 300% of their production with new gross reserves. Focusing only on the reserve replacement ratio, there appeared to be no depletion problem at all. Strongly growing reserves also suggested production growth should continue for the foreseeable future. Looking only at the reserve additions, the future of the global copper industry looked rosy.

Escondida, the world's largest copper mine, showed the apparent ease with which production could be replaced by ample new resources. In 2000 Escondida reported "measured and indicated" resources of 2.9 bn tonnes of ore reserve containing 32 mm tonnes of copper. By 2012 measured and indicated resources had grown to 9.1 bn tonnes containing 54 mm

tonnes of copper. Between 2000 and 2014 Escondida produced over 15 mm tonnes of copper. Not only had the operators of Escondida replaced everything produced, but they had grown their copper resource base by almost 70%. At first glance, Escondida's results, as well as those of the copper industry as a whole, looked very impressive and did not suggest a depletion problem.

However, a completely different story began to emerge as we analyzed the industry data more closely. After studying the various sources of the copper industry's reserve additions, we realized very few new discoveries had been made. Nearly 80% of the industry's gross new reserves booked between 2001 and 2014 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 — a process known in the industry as "lowering the cut-off grade."

Copper companies can add reserves in one of two ways: by making new discoveries or lowering the "cut-off" grade of their existing reserve base. The "cut-off" grade is nothing more than the minimum grade needed to make a unit of rock economic to extract at a certain price in a projected mine plan.

Lowering the cut-off grade occurs when mining companies assume higher forecasted copper prices in their production models. As a consequence, very low-grade ore, previously considered to be non-economic and waste, can now be mined profitably. In response to lowering the cut-off grade, non-economic waste rock can now be reclassified as a reserve. As the copper price rallied from 65 cents to $4.00 between 2001 and 2014, companies were able to significantly lower the cut-off grade that separated waste from ore. As the cut-off grade moved steadily lower, reserves moved steadily higher.

If lowering the cut-off grade were the major source of new reserve additions, you should expect to see the grade of new reserves added each year to move steadily lower. Turning back to our database of 24 companies, we calculated that the average grade of new reserves added each year steadily declined.

We estimate that in 2001 the grade of new reserves booked was 0.8% copper. By 2012, just after the peak in copper prices, the grade of new reserves had dropped by nearly two-thirds — to only 0.26%. So while the copper industry was able to more than replace production with new reserves, the quality of those reserves (as measured by the grade) dropped dramatically. An industry making few new discoveries, but more than replacing its reserves with lower grade material, by definition must be lowering its cut-off grade. Our models suggest almost all of the gross reserve additions between 2001 and 2014 were related to lowering of the cut-off grade.

Between 2006 and 2014, our group of 24 companies averaged 12 mm tonnes of annual copper production. Gross reserve additions easily offset production, averaging 27 mm tonnes per year. Careful analysis of these annual reserve bookings shows that new deposits were responsible for only 6 mm tonnes of new copper reserves while brownfield expansions made up the remaining 21 mm tonnes. As much as 80% of the brownfield expansions likely came from lowering the cut-off grade. We concluded this was not sustainable. Back in the second quarter of 2014 we wrote in our investor letter, "The reason the distinction of how reserves are being added is ultimately so important is that there is a natural limit on how far you can lower your cut-off grade. In other words, below a certain cut-off grade, the cost and complexity

to produce copper begins to grow exponentially. Our analysis suggests that we are quickly approaching the lower limits of cut-off grades." We concluded: "If this is correct, then we are rapidly approaching the point where reserves cannot be grown at all."

The 40-year operating history of the Escondida copper mine clearly outlines all the problems faced by the copper industry: declining reserve and head grades, depletion issues (as measured by head grade), and the limits and complexities of mining lower and lower grade ore. Over the last 20 years Escondida has been able to maintain its copper production while increasing its minable reserves. However, Escondida's ability to maintain production and significantly grow reserves is largely related to their ability to reduce cut-off grades in response to higher copper prices. Almost all copper producers followed this pattern between 2000 and 2014; however, we believe the copper mining industry has now gone as far as they can in lowering the cut-off grade further.

The Escondida copper deposit was discovered by the famous copper porphyry geologist David Lowell back in 1981. Put into production in 1990 by a consortium of mining companies that included BHP and Rio Tinto Zinc (RTZ), Escondida's minable 1990 copper ore reserves were estimated to be 1.8 billion tonnes of ore grading 1.6% copper using a cut-off grade of 0.7%. Escondida went through a decade of expansion and, by 2000, the mine was producing 1 mm tonnes of copper. For the first eight years of production, Escondida's operators BHP and RTZ mined Escondida's best ore. Between 1990 and 1999, the average copper head grade of the mine averaged 2.85%, well above the mine's reserve grade of 1.6%. Ore being mined at head grades almost twice the reserve grade suggests Escondida's operators were making a conscious effort to mine their very best ore grade first. In the parlance of the mining trade, the operators of Escondida were aggressively high-grading their deposit. High grading, a practice commonly used in the mining industry, has both short-term positive and longer term negative effects. By mining your highest quality ore first (i.e. the ore that contains the most copper), you lower your operating costs and generate more cash. However, longer term, high-grading accelerates the decline in the quality of your reserve base as you mine your best ore first, and leave behind lesser quality ore to be mined later. If the operators were aggressively high-grading Escondida's reserves, then both ore grades and head grades should decline. In Escondida's case, this is exactly what we saw.

After eight years of aggressive high-grading, the copper contained in Escondida's remaining ore reserves had declined dramatically. By 2000, ore reserves had reached 3 billion tonnes (primarily from the inclusion of the Escondida Norte deposit), however the grade had fallen from 1.6% in 1990 to 1.1% in 2010 — a drop of over 30%. Escondida's head grade began to fall rapidly and copper production began to decline sharply. In 1998 Escondida's head grade was still 2.75%, but by 2002 Escondida's head grade had fallen to 1.6% — a drop of over 40%. Reflecting this big drop in head grades, Escondida production fell from 1 mm tonnes of copper in 2020, to only 750,000 tonnes in 2002. In order to stem production weakness related to declining head grades, Escondida's operators in 2002 commissioned the "Phase IV" expansion project. In 2005 the Escondida Norte deposit was brought into production, and additional SX-EW capacity for the treatment of lower grade oxide ore was added. By 2004 copper production was growing again; however, reserve and head grade data clearly showed depletion issues were still firmly embedded in the deposit.

Between 2002 and 2006, the average copper head grade mined at Escondida stabilized; however, Escondida's operators were still mining ore with twice the head grade of the reserve

grade. Escondida's 2002–2006 head grade averaged 1.6% head grade, more than double the 0.78% copper grade of the ore reserves. Given the aggressive high-grading efforts, it was predictable that both ore grade, followed by head grades, should show further steep declines. This is exactly what we saw. Between 2005 and 2012, Escondida's ore grade fell from 1.0% in 2005 to 0.59% in 2012 — a drop of over 40%. In response to dropping ore reserve grades, Escondida's head grade fell from 1.6% in 2005 to 1.13% in 2012 — a drop of 20%. Reflecting the fall in Escondida's head grade, copper production steadily declined. By 2007 copper production peaked at almost 1.4 mm tonnes; however, by 2012, it had fallen back to 880,000 tonnes. Escondida's operators announced another major expansion project aimed at increasing the milling and concentrating of sulfide ores in an effort to offset declining production. A new concentrator was to be build, an old concentrator rebuilt and expanded, and a new water desalinization plant was to provide additional water for the new concentrator. Sulfide milling capability, which stood at 220,000 tonnes per day in 2012, was expanded to 375,000 tonnes per day by 2017 — a massive 70% increase.

Between 1992 and 2007 Escondida went through four major expansions, which ultimately increased copper production by over 1 mm tonnes. These four expansion projects together cost $2.5 bn and raised Escondida's copper production from 300,000 to 1.3 mm tonnes. In contrast, the 2012 expansion project, when completed in 2017, cost over $7.0 bn. Remember our comments on how the capital costs rise exponentially as head grades get lower and lower? Even though Escondida's last expansion cost 180% more than the previous four expansions combined, the $7 bn of capital spending could only stabilize and not grow production. Escondida's copper production in 2020 still sits almost 10% below 2007 production levels.

However, the depletion treadmill continues to turn for Escondida. Since 2012, Escondida's ore reserve grade and operating head grade continue to slip. Ore reserve grades fell from 0.59% to 0.57%, and head grades fell from 1.12% to 0.84%. Even with the big decline in head grades, the Escondida deposit is still being high-graded. The operators of Escondida are still mining ore at head grades almost 50% above reserve grades — giving us a strong indication that both reserve grades and head grades will continue to decline.

We have now fully updated our 2014 study on copper reserves. Between 2011 and 2016, copper prices sold off materially, eliminating the ability to further lower cut-off grades. With this avenue of reserve growth closed, the industry once again found itself faced with depletion problems that significantly impacted reserve additions. After having boasted a reserve replacement of nearly 300% over the previous decade, our group of companies were barely able to replace production between 2014 and 2020. Copper production from our group of 24 companies went from averaging 12 mm tonnes between 2006 and 2014 to 13 mm tonnes between 2014 and 2020. At the same time gross copper reserve additions collapsed from 27 mm tonnes annually to 13 mm tonnes.

The slowdown was driven by disappointing brownfield additions, just as we had predicted. New mine reserve additions were largely constant over the two periods, averaging 5 mm tonnes annually. Brownfield reserve additions, no longer propelled by an ever-falling cut-off grade, collapsed by almost 65% from 21 mm to 8 mm tonnes per year. In 2014 we predicted the industry's underlying depletion problem could no longer be masked by changes to cut-off grades and that reserves would soon stop growing. This is exactly what happened.

FIGURE 3 Reserve Changes per Year (mm t)

	2006–2014	2014–2020	Change
New Mine Additions	5.5	5	-9%
Brownfield Reserve Additions	21	8	-62%
Production	-12	-13	8%
Net Reserve Additions	15	0	-100%

Source: Company filings, G&R models.

Once again, Escondida provides an excellent example of the depletion problems being faced by all copper miners in our latest study. Between 2005 and 2012, Escondida's ore reserves grew from 3.2 bn tonnes to 9.1 bn tonnes and contained copper in those reserves grew from 32 mm tonnes to over 54 mm tonnes, greatly exceeding the 8 mm tonnes of copper production. However, no new exploration successes occurred at Escondida. Instead nearly 100% of the reserve additions that took place between 2005 and 2012 occurred because high copper prices allowed Escondida's operators to lower the mine's cut-off grade. In 2005 we estimate Escondida's cut-off grade was close to 0.45%. By 2012 the cut-off grade had been lowered to 0.27%.

The impact of a lower cut-off grade can be easily seen in Escondida's reserve report. In 2005 Escondida's ore reserves had a grade of 1.0%; by 2012 the grade had fallen to 0.6%. The copper bear market, which started in 2011, prevented further cut-off grade lowering from being the primary source of additions to reserves. After peaking at 9.1 bn tonnes in 2012, Escondida's reserves have fallen to 8.8 bn tonnes and reserve grades continued to fall. By 2021 reserves had fallen another 5% — from 0.60% to 0.57%. Contained copper in these ore reserves, which stood at 54 mm tonnes in 2012, had fallen to 51 mm. Between 2012 and 2020, Escondida was unable to replace all of its production with new reserves.

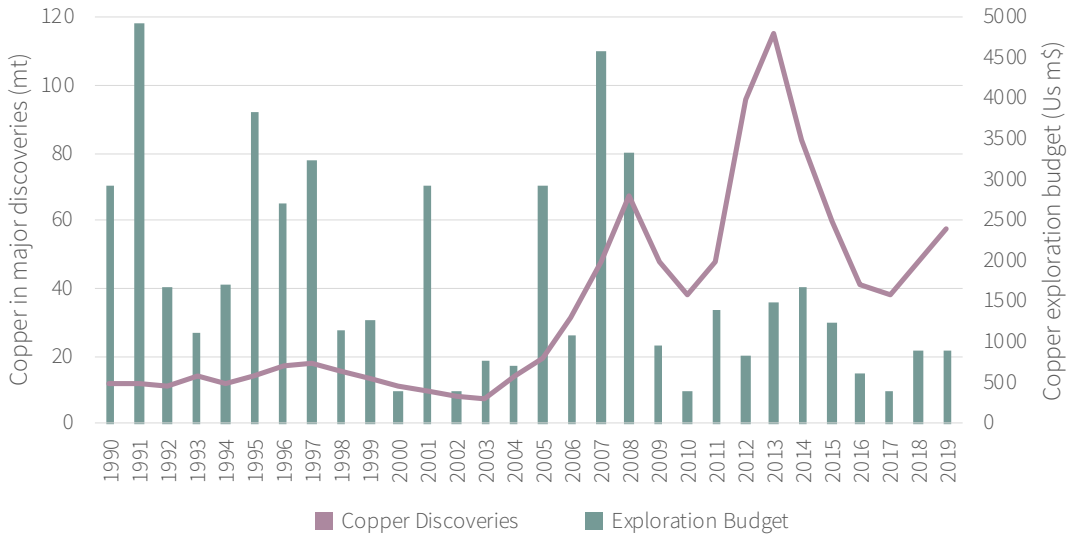
Between 2005 and 2012, Escondida added almost 30 mm tonnes of copper and replaced 275% of the reserves it produced — almost all by aggressively lowering the mine's cut-off grade. Between 2012 and 2020, falling copper prices prevented Escondida's operators from lowering cut-off grades and reserve additions plummeted to only 4 mm tonnes. The reserve replacement ratio had fallen form 275% to only 50%.

"GOING FORWARD, THE SUPPLY STORY WILL GET EVEN MORE BULLISH AS ALL THESE TRENDS CONTINUE TO ACCELERATE. OVER THE PAST TEN YEARS, NEW COPPER DISCOVERIES HAVE SLOWED DRAMATICALLY."

Going forward, the supply story will get even more bullish as all these trends continue to accelerate. Over the past ten years, new copper discoveries have slowed dramatically. Since there is often a multi-year lag between new discoveries and reported reserves, Greenfield additions will likely disappoint as we proceed through the decade. S&P Global Market Intelligence estimates that new discoveries averaged nearly 50 mm tonnes annually between 1990 and 2010. Since then, new discoveries have fallen by 80% to only 8 mm tonnes per year. At the same time, copper exploration budgets have increased more than three-fold from ~$800 mm annually between 1990 and 2010 to $2.5 bn annually since 2010, implying capital intensity surged 18-fold from $17 to over $300 per tonne. The tremendous amounts of exploration dollars being spent show little in the way of exploration success.

Brownfield reserve additions will likely continue to disappoint as well. Since 2013, the industry mostly held its cut-off grade unchanged as copper prices sold off and reserve

FIGURE 4 Copper Discoveries & Capital Expenditures



Source: S&P Global Market Intelligence.

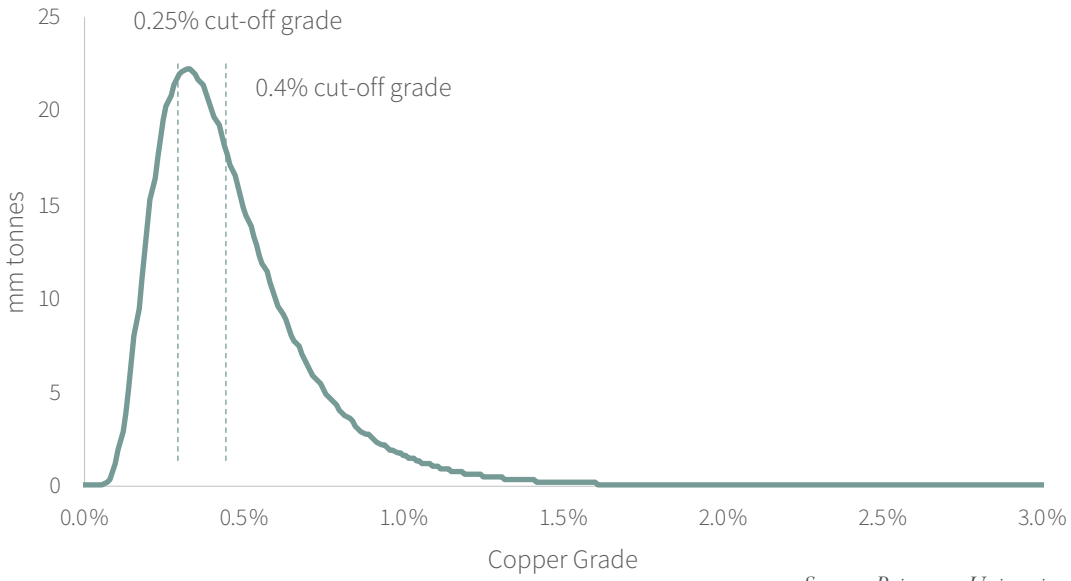
additions plummeted. We think prices are heading significantly higher. If we are so bullish, is it not possible that much higher copper prices will again allow copper mining companies to bring uneconomic ore into their reserve basis, just as they did between 2005 and 2014? Now that prices are making new highs, should we not expect cut-off grades to be lowered again, resulting in accelerating and significant brownfield reserve additions as we progress through this decade?

Our research tells us the copper industry's ability to increase its reserve base by lowering its cut-off grade is nearing an end, regardless of how high copper prices go. It is a complicated but very important subject based on how copper porphyry deposits are geologically formed. This whole subject is not well understood by most copper analysts. Since 80% of the world copper is mined from copper porphyry deposits, please let us explain.

Copper porphyry deposits tend to have a predictable relationship between grade and tonnage. In other words, for a given copper porphyry, a reserve engineer can plot the quantity of ore for each given grade. As you can see below a porphyry grade-tonnage plot does not look like a normal curve but instead has a long right tail. It turns out that the grade-tonne distribution in every copper porphyry deposit is "log-normal." A log-normal distribution differs from a normal distribution in that it is not symmetric about its mean, but rather exhibits a shallow tail extending from the right side on the horizontal axis and a very steeply descending tail approaching zero on the left side. All copper porphyry deposits display a log-normal distribution. The shape of this curve is important because it provides us with a way of estimating the ultimate potential expansion of an individual resource by further drops in cut-off grade assumptions. Also, the shape of the log-normal curve tells us that the massive expansion of existing copper reserves from dropping the cut-off grade further cannot be replicated.

Above is an idealized grade-tonnage plot for a large hypothetical copper porphyry deposit. This hypothetical deposit has 1 billion tonnes of resource grading 0.5% copper or 4.6 mm tonnes of contained copper. Until the mid-2000s, a 0.4% cut-off grade was typical, which meant everything to the left of the dashed line was considered waste rock. The remaining

FIGURE 5 Idealized Copper Grade-Tonnage Curve



Source: Princeton University.

ore above the cut-off grade totaled 500 mm tonnes grading 0.64% copper or 3.3 mm tonnes of contained metal.

In 2014, we explained how the cut-off grade had likely been reduced from 0.4% to 0.25%. According to our hypothetical grade-tonnage curve this would add an incremental 340 mm tonnes of new brownfield reserves at 0.33% copper or another 1.1 mm tonnes of contained metal. Total reserves would therefore go from 3.3 mm tonnes of contained copper at 0.64% to 4.4 mm tonnes at 0.51%. Between 2004 and 2014, our models suggest the average grade of new brownfield reserve addition was 0.25% — very much in-line with what our idealized grade-tonnage suggested. Furthermore, such a reduction in overall reserve grade implies over 30% more material (and hence capital) is required to produce the same amount of contained metal, again consistent with actual industry trends.

Lowering the cut-off grade clearly cannot go on indefinitely; unlike interest rates there is a firm low at zero. More important, the log-normal shape of the grade-tonnage plot means that most of the reserves have likely already been added. Most reserves are located on the right side of the mean where the grade-tonnage curve has a long tail. On the left hand side of the mean, the log-normal distribution shows that the grade-tonnage curve has a very short tail with far few reserves. For example, taking the cut-off grade down by 0.15% from 0.4% to 0.25% added an incremental 1.1 mm tonnes of new copper reserve. Taking the cut-off grade down another 0.15% from 0.25% to 0.1% would only add another 300,000 tonnes of contained copper — 70% less than going from 0.4% to 0.25%. At that point, reducing the cut-off grade to zero would only add an incremental 2,000 tonnes of contained copper reserve.

Because the grade-tonnage plot is not symmetric, once you hit a certain cut-off (typically near the mean resource grade), it is no longer possible to add large amounts of reserves. Given the average resource grade of a modern porphyry is likely in the 0.3–0.4% range, the industry is probably already past the point of adding reserves by lowering the cut-off grades. The log-normal shape of the copper porphyry grade distribution prevents further signifi-

cant reserves additions once you pass the mean. The steeply dipping left-hand tail make significant reserve additions impossible — the reserves are just simply not there. The copper mining industry was able to use high copper prices to more than replace production with new reserves between 2005 and 2014 by lowering the cut-off grade. In the next copper bull market, the copper industry will not be able to add reserves by lowering the cut-off grade — no matter how high copper prices go.

It is extremely likely that over the coming years, copper supply growth will remain muted. There are new projects coming online, including Kamoa/Kakula in the DRC and the Oyu Tolgoi block-cave (once major geotechnical issues are resolved), however our modeling suggests these will likely serve to offset depletion from existing operations. Given the huge slowdown in discoveries, the weak reserve additions over the past decade, and the inability to add reserves by lowering the cut-off grade, it seems difficult to see how reserves and production can grow materially.

The copper bull market is now underway. Investors are beginning to appreciate the demand story surrounding copper but most investors do not understand the complex issues now affecting supply. Between 2000 and 2020, high copper prices allowed companies to grow their reserve basis even in the face of limited new copper discoveries. Because of increasing depletion issues, the lack of new world class mines coming online, and geological constraints embedded in copper porphyry deposits, our research tells us that copper supply will show little growth this decade. Strong demand is about to collide with severe copper supply problems. Copper prices are heading much, much higher.

Natural Resource Market Overview 1Q2021

Global commodity markets in 1Q21 continued to show significant strength. Despite surging COVID-19 cases and bleak press coverage, commodity prices continue to suggest strong economic growth lies ahead. Successful vaccine rollouts — more successfully in the US, Britain, and Israel, less successfully in Europe and Canada — point to a strong rebound in global travel and economic activity as the global economy reopens. Commodity prices as measured by the Goldman Sachs Commodity index, which has a very high energy weighting, rose 14% in 1Q21. Since bottoming at the end of April last year, the index has advanced over 100%. The Rogers International Commodity Index, which has a large agricultural exposure, rose 11% during the quarter. Since April 2020, the Roger's commodity index has advanced almost 75%.

Natural resource equities also showed considerable strength in 1Q21. The S&P North American Natural Resource Sector index, which has significant exposure to energy, rose over 19% during the quarter. Since bottoming March 2020, the index has advanced 110%. The S&P Global Natural Resource index, which has more international mining and agricultural exposure, rose 12% during the quarter. Since it bottomed in March 2020, it too has advanced over 100%. For comparison purposes, the S&P 500 Index rose 5.8% during 1Q21.

Commodities with the greatest perceived economic sensitivity (oil and copper) continue to lead the market. Oil rose a significant 20% during the quarter and has now recovered all its COVID-19 losses. The oil market has slipped into a severe structural deficit. Oil

prices are headed much higher and investors should maintain significant exposure to oil related investments. Please see the oil section of this letter for an in-depth discussion regarding supply and demand.

Copper rose 17% and now sits 50% over its pre-COVID 19 highs. Copper continues to lead the bull market in base metals and is the first and thus far only commodity to have made a new cycle high. Copper is also the only base metal to approach its all-time high reached in 1Q2011. Copper reached $4.35 back in February 2021, within 6% of its all-time peak of $4.65 set in 2011.

Grain prices were again strong in 1Q21. Corn prices, driven by continued large buying of both feed corn and ethanol by the Chinese, rose 17%. Soybeans rose 9% and wheat, in response to better global weather conditions, declined 3%. As we wrote last quarter, we believe 2021 could potentially see the beginnings of a global agricultural crisis. Global grain markets will continue to see continued tightening as the northern hemisphere planting, growing, and harvest season progresses. The United States Department of Agriculture (USDA) just released its 2021 US farmers' planting intention report. It was a shocker: US farmers now plan to plant almost 5 mm fewer corn and soybean acres versus the most recent surveys. We remain very bullish on global agricultural markets and recommend investors have significant exposure.

Natural gas prices rose only slightly (2.8%) in 1Q21. The natural gas withdrawal season started off with extremely warm weather in both November and December. Weather turned much colder in January and February and, except for the record cold outbreak that gripped Texas and the South, the rest of the US never experienced a severe cold outbreak. March also saw the return of warmer than normal weather. Overall, the US winter was approximately 5% warmer than normal. As the 2021 withdrawal season started, US natural gas inventories stood almost 7% above normal; however, strong LNG and Mexican pipeline demand, coupled with weak supply, brought inventories back to normal levels even in the face of warmer than normal winter temperatures.

Precious metals were mixed during the quarter. Gold prices declined 10% and silver prices fell 7%. Platinum prices, pushed by the continued high level of interest in hydrogen fuel cells, rose 10% while palladium continued its 5-year bull market run, rising 7%.

Gold and silver stocks, as measured by the GDX ETF and SIV ETF, were weak during the quarter as well, falling 10% and 8% respectively. The quarter was not without some very interesting drama, especially as it relates to silver. Many of our readers remember the long-standing rumor that a large New York bank maintains an extremely large short position in the silver market — a rumor we view with skepticism. Spurred on by this rumor and eager to recreate their huge success in producing massive short squeezes in stocks such as GameStop (GME), a group of retail investors attempted to create a short squeeze in the silver market.

After two days of furious buying, retail buyers were able to push the silver price up almost 15%. Ultimately the squeeze failed and the retail investors were forced to give up. We believe this is a strong indication that the phantom short position never existed or, if it did, it was much smaller than widely believed. Silver prices are now 5% lower than before the attempted short squeeze. Before this precious metals bull market is over, we expect to see another attempt by a financial player to corner the silver market, much as the Hunt

brothers tried in 1979. As of now it is still too early in the bull market since speculators, other than the Reddit crowd, have little interest in precious metals markets.

The fundamentals for both gold and silver remain lackluster in the short term. Western physical demand continues to be weak. Central banks were net sellers of gold for the first two months of the year. Back in August of last year we recommended that investors reduce their gold exposure. Gold had become extremely expensive relative to other commodities (primarily oil, but also copper) and silver's huge catch-up rally from last April through August warned us that gold could experience a lengthy consolidation period. Since then gold has pulled back over 15%. For patient investors, we recommend using any weakness in gold and silver as a buying opportunity. For investors concerned with short-term performance, we still believe that gold remains expensive relative to other commodities and recommend an underweight position.

Uranium spot prices were flat during the first quarter at $30 per pound while contract prices averaged $34. Uranium related equities, on the other hand, fared much better rallying 23% as measured by the URA ETF. Sentiment towards nuclear power continues to improve as more investors and policy makers acknowledge its critical role in achieving carbon-free baseload energy. Although the future of nuclear power demand is mainly in China and India, we are beginning to see important shifts in Western Europe, the US and Japan. In April, Japanese regulators approved the restart of three long-idled reactors — the first time a reactor older than 40 years was allowed to resume operations. In the Netherlands, a movement against renewable energy and in favor of nuclear power emerged while similar feelings are now prevalent in the UK and the US. We have long advocated the benefit of nuclear power, particularly in the context of reducing carbon emissions. It is rare that a technology offers both better energetics (i.e., energy-in energy-out) and better carbon efficiency; nuclear power offers just that. On the supply front, Cameco announced that Cigar Lake would restart production in April although to date we do not have confirmation this has occurred. Some investors view this as bearish given the increase in production, while others view this as a bullish indication of improving demand. Meanwhile, Sprott announced an agreement with the Uranium Participation Trust to form the Sprott Physical Uranium Trust. While it remains to be seen what impact this will have, speculators believe it is an indication that Sprott anticipates a long-term uranium bull market.

Energy Transition Updates

Energy transition stocks fell sharply during 1Q21. The iShares Global Clean Energy ETF fell more than 30% from its January highs before rebounding slightly. In our last letter, we detailed many of the technical challenges faced by energy transition technologies such as intermittency, energy density, and cost. We also discussed how wind, solar, and lithium-ion based electric vehicles will be unable to address the global CO2 problem in ways expected by most investors. In our 4Q20 essay, we referenced a series of videos that we are now putting the finishing touches on now which go into much greater detail. We intend to have them ready for distribution on our website once this quarterly letter is finished. Thank you all for your patience and please "stay tuned."

Lithium-ion Electric Vehicles

"JEFFERIES PUBLISHED A RESEARCH NOTE ENTITLED "ARE EVS AS 'GREEN' AS THEY APPEAR?" IN WHICH THEY CONCLUDE AN ELECTRIC VEHICLE MUST BE DRIVEN 200,000 KM (OR 124,000 MILES) BEFORE ITS "WHOLE OF LIFE" CARBON EMISSIONS EQUALS THAT OF AN INTERNAL COMBUSTION ENGINE."

Since our last letter, several sources have confirmed many of our conclusions. On April 14th 2021, Jefferies published a research note entitled "Are EVs as 'Green' as They Appear?" in which they conclude an electric vehicle must be driven 200,000 km (or 124,000 miles) before its "whole of life" carbon emissions equals that of an internal combustion engine. Their analysis is very similar to ours and details the tremendous amount of energy (and by extension CO2) needed to manufacture a lithium-ion battery. Moreover, they point out that a typical EV is on average 50% heavier than a similar internal combustion engine, requiring more steel and aluminum in the frame. They conclude the "embedded carbon" in an EV (i.e., when it rolls off the lot) is therefore 20–50% more than an internal combustion engine.

Our analysis suggests a modern lithium-ion battery has approximately 135,000 miles of range before it degrades to the point of becoming unusable. An extended-range Tesla Model 3 has an 82 kWh battery and consumes approximately 29 kWh per 100 miles. Assuming each charge cycle has a ~95% round-trip efficiency and a battery can achieve 500 cycles before starting to degrade, we conclude a Model 3 can drive 134,310 miles before dramatically losing range. Incidentally, Tesla's Model 3 warranty covers the battery for the lesser of eight years or 120,000 miles and does not apply until the battery has degraded by at least 30%. If the Jefferies analysis is correct (and we believe it is), then an EV will reach carbon-emission parity with an internal-combustion vehicle just as its battery requires replacement. This will come as a huge disappointment for those believing that EV adoption will have significant impacts on CO2 reduction.

On March 22nd, *The Wall Street Journal* published a similar report entitled "Are Electric Cars Really Better for the Environment?" The authors agree the embedded carbon in an EV is much greater at the point of manufacturing but argue it would only take 20,000 miles to "break-even" with an internal combustion engine. By 120,000 miles they argue an EV would have emitted 45% less carbon than an ICE and that by 200,000 miles the EV would be 54% cleaner. While this report accurately identifies the large embedded carbon in the manufacturing process, we believe it makes two errors. First, it compares a Tesla Model 3 (a sedan) with a Toyota Rav4 (an SUV). An entry-level Honda Civic, which we believe is a more appropriate comparison, would improve the ICE fuel efficiency by 20%. Next, after consulting the footnotes, *The Wall Street Journal* article assumes 80 kg of CO2 emission per of battery. This estimate appears to be come from a 2019 Swedish Energy Agency report in which they reduce their carbon intensity by half compared with the year prior. The motivation for lowering their estimates was the use of "close to 100 percent fossil free energy [...] which is not common yet, but likely will be in the future."

In other words, the cost and carbon-intensity of lithium-ion batteries is predicated on renewable energy which itself requires cheap and carbon-efficient lithium-ion batteries. Even if *The Wall Street Journal* figures are accurate, we believe most investors still do not appreciate how little the magnitude of potential carbon savings from lithium-ion EVs is.

Assuming a 130,000-mile battery life, an EV would emit between 40–50% less carbon than a comparable ICE according to *The Wall Street Journal's* very generous figures. All transportation makes up approximately 25% of global CO2 emissions and passenger use is less than half of that at 10.8%. Using *The Wall Street Journal*'s figures, if every passenger

car was switched to an EV tomorrow, global CO2 would likely fall by 5%. Using the Jefferies data (which is consistent with our data), the difference would be negligible — there would be no reduction in CO2 output.

Photovoltaic Solar Power

Over the past decade, the price of PV solar power has fallen dramatically. According to BloombergNEF, between 2009 and 2020 solar's "levelized cost of electricity" fell by 86%, driven mostly by falling polysilicon prices. We estimate that polysilicon prices went from $80/kg in 2009 to as low as $9/kg in 2019 before rebounding to nearly $20 today. The conventional wisdom holds that manufacturing improvements drove solar panel cost reduction but the polysilicon price collapse played more of a role than most investors realize. There have now been several reports suggesting the collapse in polysilicon prices was driven by low-cost suppliers in Western China that utilize Uighur forced labor.

Bloomberg reported on this story in January and then again in February, March, and April and it appears as though the industry is starting to take notice. If these claims are true, besides being a human rights' tragedy, the cost of polysilicon could increase dramatically which in turn would put cost pressures on solar module costs.

"IT REMAINS TO BE SEEN IF THE ESG RATING AGENCIES WILL INCORPORATE THE ALLEGED USE OF FORCED LABOR IN THEIR SCORES. AS OF YET THEY HAVE NOT."

It remains to be seen if the ESG rating agencies will incorporate the alleged use of forced labor in their scores. As of yet they have not.

What a Difference a Year Makes (in Oil)

Exactly one year after West Texas Intermediate crude reached its historic -$37 per barrel low, the damage inflicted on global oil markets from the COVID-19 economic lockdowns has been largely repaired. Inventories have drawn down at the fastest rate on record and in a mere 12 months nearly all excess crude inventories have been eliminated. Prices are once again in excess of $60 and Brent nearly topped $70 per barrel in mid-March. Exploration and production equities (as measured by the XOP) have led the broad market higher, advancing 145% since the beginning of April 2020.

In the midst of last year's turmoil we released a podcast on March 10th 2020 discussing the severe volatility and weakness in global crude markets. We explained how falling productivity in the shales would cause the market to recover much faster than anyone expected. We advocated investors maintain or add to their energy exposure, an extremely bold call at the time. As with any prediction, we got some elements right and others wrong, but on balance we were correct. Not only has the oil market rebounded sharply over the past 12 months, but the drivers of the recovery have been consistent with our analysis. We bring this up because those same models which predicted the big oil price rebound last year continue to point to extreme tightness as we progress throughout 2021.

Global oil markets are firmly in deficit, as evidenced by rising prices, falling inventories, and growing backwardation. After having peaked in June 2020 at nearly 400 mm bbl above average, OECD inventories have drawn by 250 mm bbl relative to seasonal averages, suggesting the market has been 1.2 m b/d in deficit — the highest reading on record. We expect this deficit will grow as we progress through the year. Inventory data in the US shows continued draws relative to seasonal averages in March and April, albeit at a slower

"LAST SUMMER WE PREDICTED RECORD HIGH INVENTORY LEVELS WOULD BE FULLY DRAWN-DOWN AS SOON AS 2Q21AND THAT PREDICTION NOW LOOKS TO HAVE BEEN ACCURATE."

rate. We should point out however, that extreme weather in Texas impacted production, demand, and net imports leaving the data difficult to analyze properly. With the Texas weather disruptions behind us, we expect US inventories will again resume their sharp moves lower, and the most recent data confirms our analysis. Last summer we predicted record high inventory levels would be fully drawn-down as soon as 2Q21and that prediction now looks to have been accurate. We currently expect both excess OECD and US inventories to be completely worked off by late May — far sooner than anyone thought possible.

Reflecting the improved inventory situation, both the WTI and Brent market has gone from an extremely high $15–20 per barrel 12-month contango last April to a $4 backwardation today. Remember, a backwardated market (where future prices are below spot prices) is indicative of tight physical supplies where traders are willing to pay a premium for prompt delivery.

Throughout the past year, we explained why US shale production would be much slower to recover this cycle because of widespread depletion problems. US shale represented nearly all non-OPEC+ production growth last decade so any disappointments in US shale production would have immediate and far reaching impacts on global oil balances.

Shale production collapsed last year as companies actively shut-in producing wells (an industry first) and largely stopped drilling new wells. Shut-in production returned to the market last fall causing supply to temporarily rebound; however, we argued this would be short-lived — and it was. By the end of the year, all the shut-in production had been returned, yet shale supply was still down 1.4 m b/d year-on-year — the biggest decline in shale history.

In past cycles, shale production rebounded quickly because the industry had ample "core" locations left to drill. As prices fell, companies would focus all their activity on these best areas causing productivity to surge, largely offsetting the slowdown in overall activity. In multiple letters last year, we explained in great detail how the industry had nearly exhausted its inventory of core acreage, and we predicted how difficult it would be for E&P companies to boost productivity and production through additional high-grading. Our neural network told us that the E&P industry would not be able to offset lower activity with higher productivity. This important and fundamental shift — the first time in shale history — was missed by most analysts. Our neural network told us that shale productivity was largely flat in all three major basins (Permian, Eagle Ford, and Bakken), despite an incredible 80% reduction in 2020 drilling activity. In previous drilling downturns — 2008–2009 and 2014–2015 — drilling productivity soared as companies had ample inventories of top-tier prospects left to drill. In this drilling downtown, an 80% drilling drop with no corresponding increase in productivity is proof that you are near exhaustion in your inventory of top-tier drilling locations — a fact confirmed by our neural network.

We have entered a new era in global oil markets. The only source of non-OPEC+ growth over the past decade is now suffering signs of sustained depletion. Most analysts believe the shales will exhibit strong growth again when oil prices recover; however, our research tells us that growth from the shales will fall far below expectations in the first half of this decade.

Non-OPEC+ production outside of the US is equally challenged. In their most recent report, the IEA reports that non-OPEC+ production outside of the US was down 500,000 b/d in March compared with a year earlier. The IEA projects production from this group will grow throughout the year and that by 4Q21 supply will be 700,000 b/d higher than a year earlier. We disagree with this assessment and expect production will fall short by as much as 400,000 b/d, if not more. Exploration outside of the shales has been extremely disappointing over the past decade and new project sanctions have barely been able to replace base declines. Given the capital budget curtailments around the world, we expect non-OPEC+ production outside of the US will continue to disappoint going forward.

Meanwhile, demand is normalizing following the COVID-19 disruptions last year. Although global demand remained 5 mm b/d below its pre-COVID level in 1Q21, it continues to trend in the right direction. Notably, demand has remained intact despite a second wave of infections and global lockdowns following the Christmas season — a lockdown that still continues in many parts of the world. Jet fuel continues to be the weakest source of demand as international travel remains subdued, although increased freight volumes have helped to offset some of the decline.

Several countries have now either regained or surpassed pre-COVID demand levels. In 1Q21, Chinese demand was likely 1.4 m b/d higher than the same period in 2019. Indian demand was likely within 10,000 b/d of its pre-COVID record as well. Therefore, the two largest sources of demand growth in recent years are now back to their pre-COVID levels. Surging Indian case data suggests demand may be impacted in 2Q21, but nevertheless the latent demand in the underlying economy appears very strong. This is exactly what we predicted would occur as a direct result of the S-curve. As we have explained in the past, when a country reaches a certain level of per-capita real GDP, their commodity intensity begins to move up dramatically. China and India are both firmly in their S-curve sweet spots and so it is no surprise they are the two countries that are most quickly regaining their pre-COVID demand peaks.

As the COVID-19 vaccination distribution continues to accelerate globally, we believe demand will rebound very sharply from here. Indications point to substantial pent-up demand for both leisure and business travel once restrictions are lifted. Government policies meanwhile have left savings rates at all-time highs.

Looking forward through the rest of this year, we believe oil market deficits will accelerate, causing inventories to plummet. The IEA currently estimates demand will average 97.6 mm b/d for the remainder of the year. To the extent global vaccine distribution accelerates, we believe this figure could be too low by as much as 1.5 mm b/d. Non-OPEC+ production is expected to grow by 1.8 mm b/d, driven by nearly 1 mm b/d of growth from the US shales. We simply do not believe this is likely given our modeling of core exhaustion and productivity trends. Instead of growing by nearly 1 mm b/d from here, we believe total US production will continue to fall by as much as 400,000 b/d. Based on their figures, the IEA expects the call on OPEC+ to average 44.6 mm b/d for the rest of the year compared with actual production of 41.3 m b/d in April.

Assuming OPEC+ returns production according to their recently announced schedule, the IEA expects the market to remain in deficit by 1 m b/d for the remainder the year. Making the adjustments we described (increasing demand and decreasing US shale

output), we believe the deficit will exceed 3.5 m b/d, causing inventories to approach record low levels. If our models continue to be correct, global oil markets should remain in deficit even if OPEC+ returns to producing at its all-time high levels.

As our readers know, we favor those companies with high-quality assets and sensible balance sheets that trade at favorable valuations. These companies should continue to generate material value as the cycle progresses. One metric we like to use is proved reserves per net debt adjusted share. If a company has high quality assets, it should be able to grow its proved reserves per share; adjusting for net debt helps account for capital discipline. Looking at the universe of US E&P companies, we estimate the market-cap weighted group saw proved reserves per net debt adjusted share fall by 6% for the second consecutive year. Proved developed reserves (leaving aside future undrilled locations) fell by 4%. Our position-weighted average group of companies on the other hand were able to grow proved reserves by 3% and proved developed reserves by 8%. We believe this is a quick way of confirming that we continue to identify the best remaining assets in the US shale basins.

We are entering into a new era in global oil markets. While most analysts are concerned about demand, the most important driver will likely be supply. After a decade of robust growth, the US shales are now exhausted and incremental growth will be very difficult to achieve. Two decades ago, investors worried we were running out of oil while today's investor worries that we have passed peak demand. Although we cannot say for certain what the coming decade will bring, it will almost certainly defy conventional expectation. The US shales have been an extremely prolific source of supply but we firmly believe their best days are behind them. As this realization sinks in, we believe investors will focus on those companies with the remaining high-quality assets. We recommend investors maintain sizable investments in high quality E&P and oil service companies with a sizable earnings leverage to higher oil prices.

Agricultural Markets in Deficit

"China Ramps Up Farm Imports to Cover Domestic Food Shortages" Bloomberg News 3/18/2021.

Grain prices showed continued strength during 1Q21. Corn rose an additional 16% after having surged 28% in 4Q20, driven by record Chinese import demand. Soy rose nearly 10% after having rallied 30% during 4Q20. As we write this letter, both corn and soybean continue to surge. Since the end of 1Q21, corn and soybeans prices rallied an additional 25% and 15% respectively.

Global grain markets continue to tighten, especially in the US. In the USDA's preliminary estimates for 2020–2021 corn ending stocks published in May 2020, they projected inventories would reach a "bin-busting" 3.3 billion bushels — levels not seen since the grain-glut of the mid-1980s. In an incredible reversal, the USDA spent the next six months greatly reducing planted acreage, harvested acreage, and yield estimates. By December 2020, the USDA had reduced its corn ending stocks from 3.3 bn to only 1.55 bn bushels — the lowest level in seven years (for an in-depth discussion of those reductions, please refer to "The Coming Agricultural Crisis" in our 4Q20 letter).

"ENDING STOCKS AT THESE LOW LEVELS LEAVES THE CORN MARKET EXTREMELY VULNERABLE TO ANY DISAPPOINTMENT IN PLANTING, WEATHER, OR HARVESTING."

The USDA has continued reducing corn carryout stocks, which are now reaching critically low levels. In their February World Agriculture Supply and Demand Estimate (WASDE) report, the USDA increased corn exports by 50 mm bushels (primarily to China), taking the ending stock estimate to 1.5 bn bushels. In April, the USDA increased both domestic feed use and ethanol production by 50 mm bushels while increasing export demand by another 75 mm bushels. Combined, these revisions took 2020–2021 corn ending stocks estimates to only 1.35 bn bushels — a historically low level. Ending stocks at these low levels leaves the corn market extremely vulnerable to any disappointment in planting, weather, or harvesting.

Soybean markets continue to tighten as well. The USDA first estimated 2020–2021 soybean ending stock levels would reach 405 mm bushels. Although plantings, harvest, and yields were all very close to the USDA's original estimates, export demand (again from China) was revised higher by 180 mm bushels. In the January WASDE report, the USDA had lowered ending stocks to 140 mm bushels — the lowest levels in nearly 20 years. Since then, the USDA has reduced soybean ending stocks yet again to 120 mm bushels, again driven by higher export demand. Soybean ending stocks are now at dangerously low levels. Only twice in the last 40 years have they been this low.

Given the low ending stocks, both corn and soy are extremely susceptible to any disappointments in plantings, harvest, or weather. As the 2021–2022 season gets underway, problems have already developed. Last year, US farmers originally intended to plant 97 mm acres of corn according to the USDA. However, because of low corn prices, farmers surprised the market by planting slightly less than 91 mm acres. Given today's high $5 corn price, most agricultural analysts expected US farmers would again plant 97 mm acres of corn. However, the USDA released a shocker in their March 31st 2021 planting intentions report. The USDA now estimates US farmers will plant only 91.1 mm acres of corn, only marginally higher than the extremely depressed 90.8 acres that US farmers planted last year.

While corn planting intensions surprised investors, soybean estimates were much more in line with expectations. US farmers intend to plant 87.6 mm soybean acres, up from the 83.1 mm acres actually planted last year. The combined increase in intended corn and soybean plantings this year reached only 4.8 mm acres, approximately half the 9 mm combined acres expected by analysts.

The USDA will release their first estimates for 2021–2022 ending stocks in their May WASDE report in two weeks. Whereas last year the USDA revised intended plantings down dramatically because of COVID-19-related issues, it is possible in the coming weeks or months that they will revise the intentions higher because of the recent surge in corn prices. Nevertheless, based on the current preliminary planting indications, it is easy to see the precarious situation grain markets are in today. Assuming farmers plant only 91 mm corn acres, harvest 83.5 mm acres (in-line with historical planted-to-harvested ratios), and yields reach last year's original yield estimate of 178.5 bu/ac — near all-time highs — the corn crop will reach 14.9 bn bushels or 700 mm bushels higher than last year. Driven by rebounding restaurant beef demand, increases in both US ethanol (from increased driving), and surging Chinese ethanol export demand, we estimate domestic corn demand could return to its historical highs of 12.4 billion bushels, up 300 mm bushels from last year's depressed levels. Export demand is likely to grow by at

least another 100 mm bushels from here given the recent strength in corn export markets, leaving total demand for corn at 15.2 bn bbl.

Even with the most optimistic yield assumptions, corn ending stocks will likely fall by an additional 300 mm bushels, taking inventories to levels last seen in 2012, when corn prices, driven by the extensive US drought, surged to all-time highs. Given our belief that 2021 will see stretches of less than optimal growing conditions, both corn acres harvested and yield assumptions could very well be far too optimistic.

Last summer, a massive wind storm in central Iowa destroyed almost 1.5 mm acres of planted corn, while hot and humid conditions in the Corn Belt in July and August lowered realized yields by a large 6.5 bushels per acre. If less-than-ideal growing conditions emerged again this summer and yields fell by only 3 bushels per acre, harvested corn would fall to 14.6 bn bu leaving corn stocks at 600 mm bushels, well below the levels seen in 2012 which drove prices to $8.50.

Because of higher planting intensions, soybean ending stocks are less likely to reach critically low levels. At the same time, soybean export demand remains extremely strong and so growing conditions will still need to be monitored as we progress through the season.

Weather conditions in large parts of the Corn Belt are already off to a challenged start with large sections of the western US now experiencing a severe drought. In many areas, moisture levels are so low, farmers have indicated planting is not possible at all. At the same time, North and South Dakota are experiencing very dry conditions while sections of Iowa, Illinois, Indiana, Michigan, and Wisconsin are abnormally dry. The current La Nina conditions, coupled with decreased sun-spot activity (a subject we discussed in past letters) raises the probability of disruptive weather during the growing season.

In last quarter's letter, we discussed how China had emerged seemingly overnight as one of the world's largest corn importers. While China had become a large importer of soybeans 20 years ago, its corn imports remained modest until last year, averaging less than 5 mm tonnes annually between 2010 and 2019. Driven by the need to rebuild a hog herd devastated by African Swine Flu, as well as by surging milk and protein consumption, domestic feed corn demand in China surged over the last two years.

Also, growing conditions in northeastern China were less than ideal last year: typhoons caused extensive flooding in the planting season followed by drought throughout the summer. Although official figures still put the Chinese corn harvest at 260 mm tonnes (in line with the 2019 harvest), interviews with farmers suggest the crop could be up to 10% lower than projected, implying a massive potential deficit of as much as 50 mm tonnes.

Given strong demand, and the challenges surrounding the corn supply, we have noticed that the term "structural deficit" keeps cropping up among Chinese corn analysts. Beijing has hinted at reintroducing subsidies to encourage corn planting, similar to the huge subsidy that was last implemented in 2010; however as of now no new subsidies have been announced. Even with new subsidies, it will take a several years before China's corn production could show material growth.

Chinese corn imports likely surged to a record of 17 mm tonnes in 2020 and the strength continued into Q1. China bought 5 mm tonnes of corn in January and February alone, and several leading Chinese agricultural consultants have projected imports reaching

30 mm tonnes for calendar year 2021. Even with these huge corn purchases, Chinese inventories continue to fall. Although the USDA has reduced its 2020–2021 Chinese corn ending stocks estimate from 200 mm tonnes to 196 mm tonnes, these inventory numbers are still far too large and most likely will be reduced.

The Chinese government has announced they sold 57 mm tonnes of corn from inventory between May and September last year. Yet curiously, the USDA's corn inventory estimate seems not to reflect these inventory sales. Other agricultural market followers however have incorporated these sales into their inventory estimates. For example, the United Nations Food and Agriculture Organization (FAO) has slashed its estimates for China's corn inventory figures by 54 mm tonnes, reducing it to 139 mm tonnes — nearly 57 mm tonnes below USDA estimates. Strong demand, supply problems, and falling inventories strongly suggest Chinese export demand for corn will remain extremely strong.

We are beginning to read more and more stories that reference Chinese "food security," "food scarcity," and "food shortage." Has China run up against the limits of producing more and more food for its 1.3 billion people as the country's demand for increased protein continues to surge? Is China's food demand now far outstripping domestically generated supply? Is China running out of productive agricultural land? These are questions few analysts are attempting to answer. The devastating African Swine Flu decimated up to 50% of the Chinese hog herd in 2019, clearly causing a temporary surge in grain demand as the hog herd is rebuilt. But are their other long-term structural factors at work that will force China to become an ever-larger importer of agriculture-related products as the decade progresses? In future letters, we will attempt to answer some of these questions.

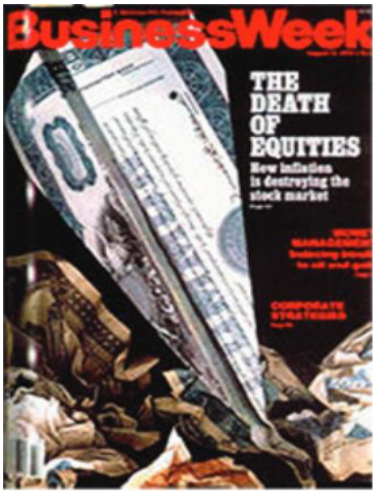
We remain extremely bullish toward grain prices as we progress through the decade. As we described in our last letter, we run high risks of slipping into a global agricultural crisis. Grain inventories are now at extremely low levels and the 2021 Northern Hemisphere growing season looks problematic. Given the strength in global grain and related protein demand and the change about to take place in global weather, namely that we have now entered a prolonged cooling cycle, global crop growing conditions will become much more challenging in the next several years. Strong demand is about to collide with climate-related supply problems. It now looks like China might become a huge wild card in global grain markets as its agricultural demands, now spilling over into exports markets, continue to increase. We recommend investors maintain significant exposure to agricultural-related equities, with a particular emphasis on fertilizer producers.

Further Ruminations on Inflation

"With Earnings Soaring, Banks See Boom Ahead" The New York Times, 4/14/2021.

A vigorous debate has emerged surrounding inflation as money supply growth dramatically accelerates, deficit spending explodes, and central banks continue to expand their balance sheets. While economists, Wall Street strategists, and policy makers, including Fed Chairman Jerome Powell, remain confident that inflationary pressure will stay subdued, anecdotal evidence suggests otherwise. Multiple stories are beginning to emerge pointing to both consumer goods and labor shortages. Investors remain more sanguine;

FIGURE 6



August 1979 – August 1982

April 2019 – ?

10-year TIPS imputed inflationary expectations are 2.3% — not materially different than in 2018 or 2019.

"REGARDING OUR OPINION ON THE INFLATION DEBATE HERE AT GOEHRING & ROZENCWAJG, WE HAVE NO DOUBT: INFLATION IS GOING TO RETURN WITH A VENGEANCE."

Regarding our opinion on the inflation debate here at Goehring & Rozencwajg, we have no doubt: inflation is going to return with a vengeance.

In 1Q19, we wrote that we had received an unexpected and extremely strong signal that inflation would return as a huge problem this decade. On April 20, 2019, *BusinessWeek/Bloomberg* magazine ran a cover story that included a picture of a dead dinosaur with the headline: "Is Inflation Dead — A New Era Has Some Frightening Downsides." We are big believers in the contrarian messages put forward by business magazine covers. Probably the best example ever of a terrible call was the August 1979 issue of *BusinessWeek* with the cover line "The Death of Equities — How Inflation is Destroying the Stock Market" in which *BusinessWeek* outlined how inflation (then considered an intractable problem) would depress equity returns for a generation of investors.

In retrospect, this was probably the worse market call ever made. Instead of intractable, the inflation problem was about to be solved. Stocks and bonds turned out to the "buy of a lifetime," and the inflationary-sensitive assets recommended by *BusinessWeek* entered into a grueling 20-year bear market only months after the publication of their cover story.

As we wrote in our 1Q19 letter, we believe the April 20th issue of *BusinessWeek* (now *BusinessWeek/Bloomberg*) will be as important as the infamous August 1979 issue.

Back in 1979, inflation had been an ever escalating problem since the end of World War II. The stock market peaked in 1966 before falling by 15% over the next 13 years. Factoring in inflation, the Dow Jones Industrial Average lost 70% in real terms between 1966 and 1979. Bonds were dubbed "certificates of confiscation" after having fallen in price for four decades, and gold and silver had become the "must-own" asset class.

By 1979, inflation had become so ingrained that even the editors of *BusinessWeek* felt comfortable enough to prematurely declare the death of an asset class that had been around for almost 400 years. Since the publication of that cover story, stocks entered

into the greatest bull market in financial history. Stocks today are 40 times higher than they were in 1979.

And inflation? Inflation peaked nine months after the *BusinessWeek* cover story and has spent the last 40 years steadily receding. For those willing to do the opposite of everything *BusinessWeek* recommended back in 1979, you were rewarded with four decades of the most phenomenal investment returns imaginable.

Today's stock market trades at record high valuation levels while interest rates have never been lower. The 30-year Treasury yield hit an all-time low of 1.25% last summer and $15 trillion of sovereign debt now trades with negative yields — a first in 4,000 years of financial history. Record-high stock and bond prices clearly signal that investors are convinced inflation will never return. Investors who read *BusinessWeek* back in 1979 were tipped off that a trend in place for years — inflation — was about to reverse with massive investment implications. Readers of *BusinessWeek/Bloomberg* in 2019, have now been tipped off that a trend in place for 40 years — disinflation — is about to reverse as well. The magnitude of the investment implication will be just as large as it was in 1979.

One of the funny aspects of business magazine cover stories is that in the short term they are perceived to be correct. The rare contrarian investor who bought the stock market in August 1979 spent the next three years frustrated as the stock market continued to drift lower, inflation continued to advance, and riskless money market yields surpassed 20%. It was not until August 1982, three years after the publication of the *BusinessWeek* article that investors suddenly recognized the financial landscape had dramatically changed. The stock market exploded off the bottom on August 17th and never looked back.

Similarly, gold investors were given a quintessential buy signal when, after 17 years of a brutal bear market, the *Financial Times* ran a December 1997 cover story entitled "The Death of Gold." Just like with *BusinessWeek*, contrarian investors who bought gold remained frustrated as prices drifted lower. Gold finally bottomed at $258 per ounce in 1Q01, three years after the "Death of Gold" story. An investor who bought gold in 1997 suffered three years of frustration and losses before gold turned into the best performing asset class of the decade.

In our 1Q19 letter, we discussed the time delays associated with both the 1979 "Death of Equities" and 1997 "Death of Gold" cover stories and we mentioned that we should expect a similar time delay to emerge following *BusinessWeek/Bloomberg*'s 2019 "Is Inflation Dead?" piece.

"TWO YEARS HAVE PASSED AND WE BELIEVE WE ARE RAPIDLY APPROACHING INFLATION'S INFLECTION POINT. MULTIPLE FUNDAMENTAL TRENDS NOW CONFIRM THIS VIEW."

Two years have passed and we believe we are rapidly approaching inflation's inflection point. Multiple fundamental trends now confirm this view. In 2019, M2 was only growing at 4% per year; today it is growing at 27% per year — the fastest rate in history. In 2019, the Federal Reserve's balance sheet stood at $4.3 tr compared with $7.3 tr today. In 2019, US government debt totaled $20 tr. Two short years later, it stands at $28 tr — up 40%.

Over the last year, the US government has borrowed and spent $2.4 trillion to replace $800 billion of lost economic activity resulting in a US savings glut of nearly $1.5 tr. Not content with the massive surge in government spending, the Biden administration is proposing an additional $3 tr in stimulus spending.

With the economy now starting to recover, the press is filled with stories of shortages that have developed in countless markets from lumber to semiconductors to restaurant workers to ketchup packets.

Economically sensitive commodities such as copper have entered into new bull markets while surging grain prices warn of significant food inflation ahead. Consumers are in excellent financial condition and have signaled their strong desire to engage in a huge catch-up consumption binge as vaccinations are successfully rolled out.

The COVID-19 economic shock has been unique in another way. Historically, large drops in GDP, such as the 32% annualized drop experienced in 2Q20, have been associated with financial panics and banking crises (for example, the 2008–2009 global financial crisis). An impaired banking system often hindered economic growth for years following the panic — again think no further back than the 2008–2009 financial crisis as a great example.

Because banks were impaired post 2008–2009, central banks were unable to stimulate lending, credit creation, or economic growth even with massive money printing efforts. Instead, most of the money printed by central banks after the 2008–2009 financial crisis ended up as "excess reserves" on central banks' balance sheets — all that printed money went nowhere.

As opposed to 2008, today's global economy is emerging from a huge economic contraction with a fully functioning banking system. Although the COVID-19-related economic lockdown caused a stock market panic (the S&P 500 dropped almost 35% in 30 days), the global banking system emerged from the economic turmoil last year in excellent shape. Thanks to that, the creation of new money is already finding its way into the economy. M2 growth is now surging at unprecedented rates — 27% at last look.

The inflation signal, first delivered by the April 2019 *BusinessWeek/Bloomberg* cover story, is now being confirmed by underlying economic and financial data. Money supply growth is surging and physical shortages are developing. The banking system is in excellent shape and stands ready to lend.

Despite these trends, investors continue to pile into technology stocks, SPACs, crypto-currencies and long-term bonds; each of which will perform terribly in an inflationary environment. In stark contrast, inflation hedges such as commodities and natural resources remain priced at record low levels relative to financial assets and are ignored by almost all investors.

The countdown to inflation is ticking and we are getting closer and closer to an explosion in inflationary pressures. All economic signs point in that direction, yet few investors are prepared to protect themselves, yet alone profit from an investment landscape that is about to suddenly and radically change. It's 1979 all over again — except in reverse.

Precious Metals Still Correcting

Gold and silver prices continue their correction. After reaching an all-time high in the first week of August 2020 at $2,065 per ounce, gold has pulled back by almost 20%. Silver peaked around the same time and began to pull back, but a furious price rally spurred by retail investors attempting a short squeeze pushed silver back to its August

2020 high. Once the short squeeze failed, silver gave back all its gains, finishing the quarter down 7%. Gold and silver stocks were weak during the quarter. Golds stocks (as measured by the GDX ETF) fell 10%, and silver stocks (as measured by the SIL ETF) fell almost 8%.

In our 3Q20 letter, we discussed how the huge catch-up rally in silver signaled that gold was entering into a potential corrective phase. Since then, gold spent the last eight months drifting lower.

For patient investors we recommend using the pullback in gold, silver, and their related equities as an opportunity to establish or add to positions. For investors with short-term performance constraints, please be mindful that gold and silver markets can go through long periods of consolidation. At the outset of the huge precious metals bull market of the 1970s, gold soared over four-fold in price between 1971 and 1974. Gold peaked in November 1974 and then spent the next two years correcting before resuming its bull market.

"DESPITE THE POTENTIAL FOR SHORT-TERM VOLATILITY, THE LONG-TERM THESIS FOR PRECIOUS METALS HAS NEVER LOOKED BETTER. GOLD HAS NEVER BEEN CHEAPER RELATIVE TO THE QUANTITY OF MONEY PRINTED. OUR TARGET PRICE FOR GOLD KEEPS CLIMBING."

Despite the potential for short-term volatility, the long-term thesis for precious metals has never looked better. Gold has never been cheaper relative to the quantity of money printed. Our target price for gold keeps climbing.

In past letters, we discussed the relationship between the size of the Federal Reserve's monetary base and the amount of gold held by the US Treasury. Over the last 120 years the dollar value of the gold held by the Treasury surpassed the size of the monetary base by an incredible 1.7 times on two separate occasions. Both times — 1937 and 1980 — investors were so scarred by current economic and political problems (in 1937 it was deflation, depression, and the gathering storm clouds of World War II; in 1980 it was just the opposite — inflation) speculators pushed gold into radically overvalued territory.

Reflecting its radical overvaluation, gold turned out to be one of the worst investments you could have made. From 1937, gold spent the next 34 years fixed at $35 per ounce by the US government (although the point was somewhat moot since Roosevelt had outlawed domestic gold ownership in 1934). In contrast, the stock market soared. Similarly, beginning in 1980 gold prices spent the next 20 years falling. By 1999 gold had declined over 70% and was universally accepted as "un-investible" (our Q4 2020 letter talks extensively about "un-investible" assets).

Today we are in exactly the opposite position. The value of the Treasury's gold holdings has never been lower relative to the size of the Federal Reserve's monetary base. Over the last 120 years gold has only twice approached today's levels. In 1970, gold was extremely undervalued. The value of the Treasury's gold holdings had gone from being 1.7 times the monetary base in 1938 to only one-eighth the value in 1970. Gold was even more radically undervalued in 2000. Years of rapid monetary expansion combined with a long drawn-out gold bear market resulted in the Federal Reserve's monetary base being priced 12 times the value of the Treasury's gold holdings. Reflecting this radical undervaluation in both 1970 and 2000, gold went on to become the best performing asset class over the coming decade.

Since bottoming at $1,050 per ounce in December 2015, gold has remained in radically undervalued territory even though it has appreciated in price by nearly 65%. The reason is simple: the Fed has increased its monetary base faster than gold has rallied.

The Fed's balance sheet was $4.5 trillion in December 2015. After experimenting with letting assets roll off in 2018, the Fed aggressively reversed course once the Treasury secondary market seized up in September 2019. Over the next six months, the Fed's balance sheet nearly regained its former size. Then the COVID-19 pandemic hit.

By the beginning of 2020, the Fed's balance sheet was $4.1 tr. As of April 30th 2021 it has exploded to $7.8 tr — nearly 75% higher than five years ago when the gold market bottomed. The Fed's balance sheet exceeds the dollar value of the US Treasury's holding by a record 14 times — significantly more than the undervaluation experienced in the late 1990s.

According to this measure, gold is now the most radically undervalued it has ever been. Even adjusting for excess reserves (i.e., money created by the Fed but placed back on the liability side of the balance sheet), gold is still radically undervalued. Removing the $2.8 tr of excess reserves presently on the Federal Reserve balance sheet, the monetary base is still 11 times bigger than the value of the Treasury's gold holdings.

Despite having rallied from $260 in 1999 to $1,750, we believe gold is more undervalued relative today than any point in history.

Assuming the value of the Treasury gold holdings once again reached the monetary base (remember in 1938 and 1980 they reached 1.7 times the monetary base), gold would have to reach $25,000 per ounce. Removing the excess reserves from the monetary base, gold would still have to reach $15,000 per ounce. To reach the historical peak of 1.7 times (which mind you occurred twice in the twentieth century), gold would have to exceed $30,000 per ounce, even with excess reserves removed.

"FOR PATIENT INVESTORS LOOKING FOR A RADICALLY UNDERVALUED UNCORRELATED ASSET CLASS WITH MASSIVE UPSIDE POTENTIAL, GOLD REPRESENTS A WONDERFUL OPPORTUNITY."

For patient investors looking for a radically undervalued uncorrelated asset class with massive upside potential, gold represents a wonderful opportunity.

For investors with performance constraints who want to carefully time increasing their precious metals exposure, we believe the present corrective phase is not yet over. Two important sources of demand remain very weak. First, central banks continue to be net sellers of gold after having accumulating over 600 tonnes in each of 2018 and 2019. Last year, they slowed their purchased dramatically (please see our 4Q2020 letter) and this trend has continued into 2021.

According to the World Gold Council, central banks were net sellers of 16.7 tonnes of gold in January and February 2021. Since June 30 2020, central banks have only been net buyers of 16 tonnes of gold, down an incredible 400 tonnes compared with the second half of 2019 and first quarter of 2020. Given the huge strains put on government finances by the COVID-19 pandemic, we could well be in a lengthy period of subdued central bank buying.

Another large source of demand, the western physical buyers, has turned from net buyers to net sellers. After steadily accumulating a huge 2,250 tonnes between May 2019 and October 2020, increasing their holdings by almost 60%, the 16 physical gold ETFs we follow have turned into persistent sellers. Since October, physical gold ETFs have sold 370 tonnes, or nearly 30% of what they accumulated in their last accumulation phase. Currently, the ETFs continue to sell gold.

Silver had a much different experience during the quarter. As we mentioned earlier, silver became the focus of an engineered short squeeze by retail investors hoping to repeat their

short squeeze success in stocks such as GameStop.

Relying on widely circulated rumors of huge silver short positions currently maintained by a large New York bank, the Reddit community began to aggressively buy silver starting in the last week of January.

The buying pressure can easily be seen in the silver accumulation of the top 10 physical silver ETFs we follow. From October 2019 to October 2020, silver (like gold) went through a huge accumulation phase. The 10 physical silver ETFs accumulated 12,000 tonnes of silver — an increase of 75%. Starting in October these physical silver ETFs began to lightly liquidate silver until the end of January. Then in a response to the surge of retail silver buying, these 10 physical silver ETF's added an additional 3,600 tonnes in only four days.

Spot silver prices rallied from $25 to $30 per ounce, but retail buyers were met with significant selling pressure and the silver has now given up all its gains. The physical silver ETFs meanwhile have liquidated all the silver accumulated during the attempted short squeeze.

The attempted short squeeze by retail investors was met with defeat this time, as we expected it would. We have never been a big believer in the rumor that the silver market has embedded within it a huge short position. The lack of success by the retail community lends credence that this short position may not exist or, if it does exist, it may not be as large as commonly believed.

Given all the drama, we would like to make some points regarding the silver market today. Silver's price action over the last six months has been notable. Since gold peaked last August, silver has been quietly outperforming gold. Since November 2020, silver is now up 10% while gold is down 10%. As we mentioned in our inflation essay in this letter, we are big believers that inflationary pressures will return much sooner than most investors believe. Is silver's quiet outperformance relative to gold telling us that inflationary pressures are also quietly building? Silver's relative strength, we believe, is giving us another signal that inflation is about to return with a vengeance.

For investors looking for an asset class with huge sensitivities to inflation, silver should be seriously considered. In the inflationary 1970s, silver appreciated an amazing 40 fold in price. It was ultimately the focus of a huge operation by the Hunt Brothers to corner the market, driving silver to over $50 per ounce — a price that is still 100% higher than the price of silver today.

Although not as cheap relative to gold as it was last year (the gold-silver ratio is 70 versus its all-time high of 125 last year), silver still has significant upside potential. In the last gold bull market which peaked in 2011, the gold-silver ratio fell to under 35. During the great precious metals bull market of the 1970s, the ratio fell to 15.

Given our belief that inflation is about to become a huge problem, we would like to emphasize two points. We believe the manipulation of silver prices last quarter by retail investors will only be the first of many attempts by speculators to "bull" the silver market this decade. Before this precious metals bull market is over, we believe another attempt will be made by either financial speculators or wealthy individuals to corner the silver market, much like the Hunt Brothers tried to do 40 years ago. In dollar terms, the silver market is only 5% of the gold market. Given the massive amounts of money creation, silver would present itself as a tempting target. Second, we believe before this precious metals bull market is over, we will see the gold-silver ratio approach the level it saw back

in 1980 — 20 or below. If gold hits our $15,000 target and the gold-silver ratio falls to 20, this implies a silver price of $750 per ounce — 30 times higher than today's price.

In summary, the corrective phase in gold remains in place. Although gold demand remains extremely strong in India, conflicting demand signals are still emanating from China. However, central bank gold buying has receded to almost nothing and western physical gold demand has now turned into a source of supply. The loss of this demand from both central bank and western investors is pressuring the gold price. We are carefully monitoring the potential return of demand from both sources. For long-term patient investors, you are again being presented with another great buying opportunity in both gold and silver. For investors with shorter time horizons, we still believe that depressed markets such oil, natural gas, and agricultural fertilizers offer greater opportunity in the short term.

Gas Getting More and More Bullish

Natural gas prices were flat during 1Q21. Weather was a near-constant negative headwind in North American natural gas markets this winter. November and December were much warmer than normal while January was near normal and March was 10% milder than normal. Only February was colder than normal by 15%, but this was not enough to offset the other months. Overall the 2020–2021 withdrawal season was 5% warmer than 10-year averages.

Despite the mild winter, storage withdrawals were higher than average. US inventories started the withdrawal season 200 bcf (or 5%) above 10-year averages before working off nearly all of this excess by the beginning of the injection season. Inventories finished the winter season only slightly above average.

US natural gas supply continues to show limited growth. Production over the last four quarters averaging 91.2 bcf/d, down 5.6% year-on-year. Although January production was up 1.3 bcf/d compared with Q4, it remained 2.6 bcf (or 3%) below the same period last year.

"PRODUCTION ESTIMATES FROM THE ENERGY INFORMATION AGENCY'S (EIA) APRIL DRILLING PRODUCTIVITY REPORT SUGGESTS NO GROWTH THROUGH AT LEAST MAY."

Production estimates from the Energy Information Agency's (EIA) April Drilling Productivity Report suggests no growth through at least May.

The US natural gas rig count remains far below the level needed to keep production flat, let alone grow. After having peaked at 200 rigs in February 2020, the US natural gas rig count fell to 68 rigs in July before rebounding to 94 rigs today. Our models suggest today's activity levels are still too low to offset base declines, resulting in continued declines.

Notably, activity remains subdued in the Marcellus. Over the last 10 years, the Marcellus has been the driving force behind surging US natural gas supply. From almost zero production in 2010, the Marcellus produces almost 30% of US gas supply today.

In previous letters, we discussed how the Marcellus and Haynesville were rapidly reaching a point where production would plateau and begin to decline. According to our neural network, both plays were reaching the same geological challenges faced previously by the Barnett and the Fayetteville, immediately before they plateaued and started declining.

Barnett production grew rapidly in the early 2000s. Production unexpectedly plateaued in 2013 and peaked at almost 5.5 bcf/d in 2015 before entering into a persistent decline. Production from the Barnett is now only 2.3 bcf per day, almost 60% below its peak. In

the case of the Fayetteville, production ramped up sharply in 2007, began plateauing in 2012, peaked at almost 3 bcf per day in 2013, and then began its steep decline. Presently, Fayetteville production averages 1 bcf/d — 65% below its peak.

What caused the plateau and then steady declines in both plays? According to our neural network, drilling productivity plateaus once 40% of tier 1 locations in a play have been dilled. Productivity begins to fall once 60% of tier 1 locations have been drilled. In the case of the Barnett, 40% and 60% of tier 1 prospects were drilled in 2013 and 2015, respectively. By 2015, production in the Barnett peaked and began a persistent decline. In the case of the Fayetteville, 40% and 60% of tier 1 prospects were drilled by 2012 and 2014, respectively. Production in the Fayetteville began to peak in 2011 and by the end of 2014 production began its steep decline.

Our neural network tells us that 60% of tier 1 Haynesville wells have now been developed and 40% of tier 1 Marcellus locations have been drilled. If our analysis is correct, the Haynesville will begin to experience chronic declines soon while Marcellus production will begin to plateau. By 2023, we estimate 60% of the tier 1 Marcellus locations will have been developed and production will fall.

The Haynesville plateaued in the beginning of 2019 and production has since been flat. Likewise, Marcellus production stopped growing in mid-2019 and has also been flat since.

The Marcellus rig count peaked in 1Q19at 68 rigs, just as production began to plateau. Even before the COVID-19 lockdown took hold, the rig count in the Marcellus had declined by 40% to 40 rigs. Marcellus rigs collapsed to 24 last September during the worst of the COVID-19-related economic dislocations. Today it has only rebounded modestly to 29 rigs.

Production in the Marcellus stopped growing with close to 70 rigs drilling for natural gas. With only 29 rigs operating, production will soon begin to decline. Our neural network puts forth strong evidence why the Marcellus has seen such rig count weakness. At the beginning of 2019, 40% of tier 1 drilling locations had been drilled. Today that figure stands close to 50 %. We believe the weakness in Marcellus drilling activity strongly reflects the dwindling number of Tier 1 locations left to drill.

A similar pattern has emerged in the Haynesville. The rig count in the Haynesville peaked in Q1 of 2019 at 58 rigs just as production began to plateau. The rig count then fell 27% to 42 rigs before COVID hit. During the worst of the pandemic, 31 rigs were drilling in the Haynesville.

Since then the Haynesville rig count has rebounded to only 45 — still almost 35% below its 2019 peak.

Our neural network tells us that nearly 60% of tier 1 wells have now been drilled in the Haynesville and, just as in the Marcellus, we believe the weakness in the Haynesville rig count reflects the dwindling number of tier 1 well locations left to drill.

The importance of the Marcellus and Haynesville gas play cannot be overstated. Since 2006, US natural gas production has grown 90% and the Marcellus and Haynesville represent over 75% of this growth.

The severe production declines in both the Barnett and Fayetteville shale gas fields clearly

show what happens when top-tier drilling locations become exhausted: field production begins to decline. The process is about to grip both the Marcellus and Haynesville shale gas fields, with huge bullish implications for US natural gas prices.

Overall demand for US natural gas remains strong. Gas demand for US LNG exports continues to rise. Aided by the commissioning of Cheniere's Corpus Christi Train 3, natural gas feedstock demand has now reached 11.5 bcf /day, up nearly 25% year-over-year. With that, US export capacity has now reached 10.8 mm bcf /day. Given the strength of global LNG demand, we expect to see close to 10 bcf per day of LNG exports in 2021, up 50% from last year's COVID-19 impacted levels.

Natural gas pipeline exports to Mexico continue to rise sharply. The recent completion of two new pipelines and the expansion of an important compression station has caused US gas exports to Mexico to reach a new record of 7.7 bcf per day, up nearly 50% from a year ago. Also, the completion of the Tula-Villa de Reyes pipeline, scheduled for later this year, will add almost an additional 1 bcf /day of export capacity to Mexico.

The great bear market in gas over the past 13 years was caused by surging supply. Our research tells us that natural gas supply growth in the US will slow dramatically, if not turn negative, in the next several years. At the same time, domestic and export demand for US natural gas continues to grow. The bull market in natural gas has begun with little attention from the press. We recommend investors own a diversified portfolio of natural gas-related equities. Valuations are very low and natural gas prices are going much higher.