

Comments by Michael Mew (Referee) on:

Comment on: "Recent revisions of phosphate rock reserves and resources: a critique" by Edixhoven et al. (2014) – Phosphate reserves and resources: what conceptions and data do stakeholders need for sustainable action?

R. W. Scholz and F.-W. Wellmer

Introduction

The paper presented by Edixhoven et al. discusses a number of topics on phosphate rock reserves and resources and presents a number of recommendations. In particular, Edixhoven et al. argue that the report by the IFDC in 2010 presents a misleading picture of future phosphate rock availability.

Scholz and Wellmer present a number of criticisms of the Edixhoven paper, but acknowledge a number of areas where the paper makes useful suggestions, in particular the use of a more precise language in reserve/resource discussions.

From a geoscience background I have spent almost 40 years as a consultant to the phosphate industry, mainly working on market and economic studies. I was editor of the 4th edition of World Survey of Phosphate Deposits (British Sulphur Corporation, 1980). I was part of the UN IGCP Project 156 in the 1980's, the results of which were published as four volumes, including Phosphate Deposits of the World Volume 2, Phosphate Rock Resources (Notholt et al, 1989). In 1980 I worked with industry consultant Zellars-Williams on the US government-funded Minerals Availability System review of Phosphate Rock deposits. I have also been actively engaged in two major industry studies that profiled the economics of major phosphate deposits worldwide, both those being actively mined together with major undeveloped deposits; these studies were undertaken in 1981-1984 with Zellars-Williams/SRI International/Fertecon, and in 2013 with CRU international.

In 2011, I became involved in the 'Peak Phosphate' debate (Mew, 2011) as I thought the analysis being presented by studies such as Dery & Anderson (2007), and Cordell et al. (2009) contained flaws. This led to my participation in the Global TraPs project as an industry participant. Working in a transdisciplinary environment, it became clear that there was a significant lack of knowledge flow from academia to industry and data and knowledge flow from industry to academia.

Summary of Comments

I agree with Scholz and Wellmer that the degree of granularity in reserve/resource classification should reflect the requirements of the use to which it is to be put. I also agree that we should use the fewest categories that give sufficient confidence in the data. High granularity demands high levels of detail in the data and runs risk of excluding deposits that don't meet that data detail.

Setting up an independent international panel of expert persons is probably the only way of transferring and collating deposit data. Much data exists in the industry, but is usually commercially sensitive. Given the degree of subjectivity in determining reserves/resources, the use of 'competent persons' on such a panel would be essential.

The use of the PR-M and PR-Ore terminology suggested by Scholz and Wellmer is a good idea and I believe it should become standard practice to use such terminology in all discussions of reserves/resources. Reporting ore reserves in terms of PR-M has been common practice by some large producers, but not by all. This has led to confused reporting in the past.

Determining a meaningful number for reserves is important in early warning type discussions (such as R/C etc), but much less so in discussions of long-term phosphate rock availability. OCP's own reserve/resource total increased through the 25 years to 2004 as new geological prospecting work was done. How much of it can be called 'reserve' is largely irrelevant to longevity calculations as essentially all is expected to be made available at some future point, if required by the market, due to the nature of the deposits in Morocco and the inherent low value and price flexibility of PR-M as noted by Scholz and Wellmer.

Given the major change to industry economics (PR-M price changes) in the 2006-2014 period, one would expect there to have been increases in phosphate reserve levels as more ore in the reserve base category becomes viable at 'today's economics'. The realignment of Moroccan reserves suggested by the IFDC in 2010 is therefore not counter intuitive. However, the increase in Moroccan reserves was not a result of a fundamental recalculation based on production economics by the IFDC – rather it was triggered by a reassessment of data already in the public domain. Similarly, a lack of increase in reserve data for Morocco in the 2008 and 2009 USGS Mineral Commodity Summary is also noteworthy, given the change in PR-M price levels. This leads me to question the viability of the USGS position in dropping its Reserve Base category, due to lack of financial resources with which to recalculate deposit economics, whilst at the same time retaining a reserve estimate which also depends on the economics of the day.

Discussion

In each of its Annual Reports, going back at least to 1979, OCP gives an overview of exploration work it has carried out in the previous year, together with a table of total ore volumes in cubic metres. In the 1979 report, the data are split by regional deposit, with the "explored and studied" portion of the three producing regions, Oulad Abdoun, Ganntour and Oued Eddahab (BouCraa), containing a total of 14.03 Gm³ of ore. The same report also indicates that the explored and studied portion in these three areas totaled 1,719 km² out of a total mineralized area of 9,108 km².

Succeeding OCP annual reports likewise give data on prospecting activities in the previous year, but the data tables in Annual Reports after 1980 give ore volumes split by borehole grid spacing and region, but no figures for explored area and total area. In the early reports, the data are referred to as 'reserves', the exception being the 1982 report where they are referred to as 'resources'. From 1983 through 1987, the data were again referred to as 'reserves', whereas from 1988 onwards the figures are always referred to as 'resources'.

Total reserve/resource number for the three operating regions in Morocco increases steadily in successive Annual Reports from 14 Gm³ in 1979 to 70 Gm³ in 1995, despite OCP's average annual production of around 20 M tonnes of PR-M throughout the period. This increasing Moroccan reserve/resource total from 1980 through the mid-

1990's was determined during a period of relatively low international PR-M prices. I agree with Scholz and Wellmer that there would have been little incentive for OCP to exaggerate its reserve/resource position, as this would have potentially exacerbated the feeling that the market was in oversupply at this time.

Despite changing its deposit designation from reserve to resource, in its Annual Reports OCP always presents its data in terms of m^3 of ore. I think that much of the confusion from those analyzing the figures stems from the fact that, on average, 1 m^3 of OCP ore more or less equates to 1 tonne of PR-M (marketable concentrate). OCP has in the past stated this to me personally and it is clear from an analysis of various information sources that this conversion factor is used by OCP when presenting its own reserve/resource data.

In effect, OCP's Annual Reports show a growth in reserves/resources in its three producing regions from 14 Gt PR-M in 1979 to 70 Gt PR-M in 1995. Cumulative Moroccan production of PR-M in this 16 year period was 0.30 Gt (FRC/CRU data). Despite OCP's superior reserve/resource position, output of PR-M by OCP has been fairly flat through the last 25 years. At current output levels of 0.025 G tonnes per year, OCP has identified 2,800 years worth of phosphate. Even restricting the calculation to the 17 Gt that has had the most detailed (sub 500m grid spacing) exploration, OCP would have 680 years covered or 85 years if it were hypothetically asked to cover all current global requirements of 0.2 Gt PR-M.

In my opinion, Scholz and Wellmer's reference to World Survey of Phosphate Deposits (BSC, Savage, 1988) might be better redirected to refer to the UN IGCP Project 156 document (Notholt, Sheldon and Davidson, Phosphate Deposits of the World, Volume 2, Phosphate Rock Resources, Page 310, Table 47.1). Both reference a paper presented by Belkhadir and Chaoui (OCP, 1985), in which they quote ore data for each phosphate area in Morocco. The IGCP reference is more complete, however, and is in a chapter written by OCP itself. The data values in Table 47.1 are close to the values given for each area in the 1982 OCP Annual Report, except that in Table 47.1 the "resources" are quoted in tonnes, whereas in the OCP Annual Report, the similar values are quoted in m^3 . I believe OCP has converted ore volumes to tonnes of PR-M on a 1:1 basis but retained the other characteristics in Table 47.1 which refer to PR-Ore. Intriguingly, the text of the OCP chapter refers to the tonnage in Table 47.1 as 'identified mineable reserves' and references Benchekroun 1984 as the source. In addition, the paragraph goes on to say that "total resources are undoubtedly considerably larger. At the end of 1986, reserves were placed at around 64,450 million tonnes...". This 1986 figure in tonnes PR-M compares well with the 63,980 m^3 reported as ore reserves in the 1986 OCP Annual Report. Again OCP is equating 1 m^3 of ore with 1 tonne of PR-M, whilst also referring to all the tonnage at this point in time as reserves rather than resources.

Scholz and Wellmer argue that Edixhoven's criticism of the change in Moroccan reserve figure in the IFDC report is unjustified. On the whole, I agree with Scholz and Wellmer since OCP has clearly identified, through geological prospecting over several decades, more than 85 G m^3 of ore, which it equates to approximately 85 G tonnes of PR-M. As outlined above, OCP knows that there is sufficient ore mapped out at a high degree of certainty for mining in the coming decades, with the remainder at progressively less detail. How much of the 85 G tonnes is mineable profitably under today's economics is, I imagine, largely irrelevant to OCP.

OCP certainly will have seen some of its resources converted reserves as market prices have increased recently and this process, by which the market generates more production through higher prices is expected to continue. By investing considerable sums in a new slurry pipeline to replace rail transport, OCP will convert more resources into reserves, since production costs will be around \$8 per tonne lower once the pipeline is fully commissioned. The resource/reserve boundary is thus forever changing if we define it using 'today's economics'.

The interpretation by the IFDC of where the boundary lies for Morocco in 2010 forms a large part of the discussion by Edixhoven et al. In reality, only a 'competent person' (as defined by JORC etc) with access to detailed geological data can calculate such a reserve number, and then for only one point in time. What Edixhoven et al. seem to have ignored is the vast change in phosphate industry economics over the last decade, caused partly by the spike in PR-M prices in 2008, but more importantly by the stabilization of PR-M prices at over \$100 per tonne since that time, a level 2-3 times higher than pre-2008. This large increase in market price was not accompanied by a commensurate increase in production costs, and as a result, profitability can be expected to have increased significantly for OCP and other producers. This improved profitability will have converted a substantial amount of Morocco's 'resources' (using OCP nomenclature) into reserves, so it should not be surprising that there was a quantum change in the reserve figure from estimates made prior to 2008 to those post 2008. However, such a quantum change should derive from cost/value calculations, whereas the IFDC change came about through a reassessment of data already in the public domain.

It is noteworthy that the USGS did not raise its reserve estimate for Morocco in 2009 Commodity Summaries Report (reporting on 2008) despite the fact that price levels for PR-M had increased by almost a factor of 4; in fact the USGS Commodity Summary report reduced Moroccan reserves and reserve base by 3 G tonnes each, to 15 G tonnes and 47 G tonnes respectively. Meanwhile, in the USGS Minerals Yearbook, the figure of 85 Gm³ for Morocco was being quoted as the estimated **reserve** level from 2007 through to 2009. In the following year, 2010, the reserve base category was dropped in the Minerals Commodity Summaries Report, leaving Morocco a reserve of 16 G tonnes. However in the 2010 Yearbook, 50 G tonnes of proven reserves was being quoted for Morocco (presumably following the publication of the IFDC report).

The reason the Reserve Base category was dropped by the USGS was due to reduced financial resources – the USGS could no longer update the cost calculations required to determine the reserve/reserve-base boundary. Yet surely would this also not make it impossible to update reserve levels as a result of changing economics?

In fact there are private consultancy companies, such as CRU International, which perform industry-wide production cost analyses on a regular basis for individual phosphate rock mines. Scholz and Wellmer's proposal of an 'solidly funded, international standing committee' of experts to correlate global phosphate resource data is welcome as is their proposal that it should comprise expertise from both academia and industry. If the independence of such a panel was assured and its remit clearly did not infringe private data confidentiality, I believe it could attract sufficient support from resource holders globally to allow a calculation of global reserves and resources sufficient to provide at least an early warning system, if not a estimate of the global URR.

Specific Comments

P33 line 11 : "...phate is supply is doubted..." the first 'is' is not required.

P34 line 14 "1. What Knowledge do we have about phosphate reserves?" I think this section does not really deal the subject in the title – it reads more like an introduction to the paper, including a review of what later sections will deal with.

P 35 line 2: "...Survey Mineral Summaries" should be "..... Survey Mineral Commodity Summaries"

P35 line 15/16 "...system scientists, ..." should be "...system scientist's..."

P36 line 17 "... 15 Gt PR in 2010 (USGS, 2010) to 65 Gt PR (USGS, 2010)." Should be "...16 Gt PR in 2010 (USGS, 2010) to 65 Gt PR (USGS, 2011)."

P37 line 9 "...which 12 respectively 14 are used)" should be "..which 14 are used)"

P38 lines 14-16 Your statement that the authors quote a scenario in which reserve/consumption decreases to 48 years is possibly unfair as I think the 48 years is only mentioned by Edixhoven et al. in the context of being an erroneous figure.

P42 line 10 Should a reference be given for the 178.5 Mt PR-M production? IFA have 183.9 Mt and CRU have 184.1 Mt.

P46 lines 20-22 In comparing Cu grades in these three lines the terms "average", "lowest average" and "lowest" are used. It's a bit confusing.

Page 49 lines 7-13: See my comments above. Surely cost models are also necessary to quantify reserves as well as reserve base?

Page 51 line 1: "...may appear as resources in the future.." Should this be "...may appear as **reserves** in the future..."?

Page 52 line 14 has "65%" but line 15 has "1.5/.66" - should it be 66% or 1.5/.65

P53 line 15-16: I'm not sure what the sentence "This estimate was obviously due to the easy accessibility of the upper beds." means.

P53 line 21: "...areas no including..." should be "...areas not including..."

P56 line 25: "...provided or data..." should be "... provided ore data..."

P60 lines 10-11: As per my other comments, USGS reserve levels should change continually with market prices unless they are defined at a fixed price level (as were the original USBM reserve and reserve base data). I believe the USGS definition is rock that can be produced at today's economics, which would imply that as the world PR-M price changes, so too should the reserve figures.

P64 line 6: "negotive" should be "negative"