

COMMENTS BY JOOST EDIXHOVEN (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?

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1 BACKGROUND OF THE CURRENT DISCUSSION PAPER

1. The discussion paper by Scholz and Wellmer responds to a paper which I published together with Prof H.H.J. Savenije and Prof. J. Gupta (Edixhoven et al, 2014). Our paper investigates the major increase of reserves as reported in a report by IFDC (the IFDC report; Van Kauwenbergh, 2010), which report was published following the recent debate on peak phosphorus (Cordell et al. 2009). IFDC reported a 4-fold increase of global reserves. In the IFDC report, the increase of global PR reserves based was on an increase of Moroccan PR reserves, from 5,700 Mt PR in the USGS mineral Commodity Summary to 51,000 Mt PR in the IFDC report, reported as upgraded concentrate. The increase was based on one single publication (Gharbi (1998)). In its report, IFDC indicated that it would not use the definitions in the USGS classification, which poses requirements for reserves and the reserve base in terms of the economic viability of a deposit and the degree of geologic assurance. One year later, this increase in reserves was accepted by USGS, based on the IFDC report and information from the Moroccan producer, OCP (USGS, 2011). Shortly afterwards, reserve for a number of other countries were increased in the USGS records, one of which (Iraq) was downgraded again shortly afterwards (see, our paper and the discussion paper).
2. In very brief summary, our research questions and conclusions were as follows:
 - (i) Are the terminology proposals by IFDC, which entail a significant simplification of the USGS requirements, likely to yield data which are reliable and comparable? Following a review of various types of resource classifications and their rationales, we concluded that discarding the underlying thresholds for reserves appears undesirable as this is likely to impair reliability and comparability of reserves data.
 - (ii) Is it common to report reserves as concentrate and is the difference between PR concentrate and in situ PR ore sufficiently understood in the literature? Here, we concluded that reporting of reserves in concentrate is not expressly prescribed by the USGS classification and other classifications and that the difference between ore and concentrate has barely been noted in the literature. We noted that reserve numbers for a number of other countries in USGS' mineral commodity summaries appear to represent ore rather than concentrate. USGS has meanwhile confirmed this. We also noted that a failure to consider the difference between in PR situ ore and PR concentrate has caused pervasive confusion and a significant number of recent flawed assessments of, in particular, the static R/C ratio of resources.
 - (iii) Is the restatement of the Moroccan reserve in the IFDC report (which was subsequently accepted by USGS) reliable and comparable? Our main conclusion was, based on a number of documents, including a paper by Gharbi and M'Chichi (1996), a number of OCP documents and a statement by the author of the IFDC report (Van Kauwenbergh, 2006), that the single paper on which IFDC based its estimate of Moroccan reserves (1998) appears to offer an inadequate basis for its restatement of the Moroccan reserves. Here, as an additional rough indication, we also compared drillhole data for the Moroccan ore fields as provided by OCP with USGS drillhole requirements for some of the USGS deposits, whilst stressing the uncertainty related to this aspect of our analysis.
3. Our paper attracted four peer reviews, the first by an anonymous reviewer; the second Scholz and Wellmer, the third by prof, Cook and the fourth by prof Hilton (to be obtained via the ESD web site). The second peer review report was issued by Scholz and Wellmer. Mr. Scholz is initiator and CEO of the Global TraPs Project, together with the CEO of IFDC, Mr. A. Roy (see, introduction of our paper). Mr. Wellmer published a number of publications together with Mr. Scholz in the context of the Global TraPs project. The extensive review report by Scholz and Wellmer identified 7 "concerns" relating to our paper. In it, they strongly criticized our paper on a range of issues. However, my co-authors and I were of the view that,

while the review by Scholz and Wellmer contained a number of useful suggestions which we incorporated in our paper, the review hardly discussed the research questions and our analysis of our paper. We issued an extensive response consisting of a cover paper and a matrix in which each of the comments made by Scholz and Wellmer was discussed in detail (Edixhoven et al. 2014b). In the cover paper, we noted the following:

Having carefully compared the review to our paper, there apparently is some misunderstanding as to what a scientific review entails. To review a paper implies that the reviewer discusses the research questions, the methods used and the research findings. However, unlike the first review, the second review does not discuss the research questions and their relevance, while only fractions of our methodology and research findings are discussed. Moreover, part of the reviewers' criticism appears to be that we should have discussed other issues in our paper (e.g. the dynamics of reserves and resources) which essentially entails that we should have written another paper. But the request to write a different paper is not based on a critique of the questions we have posed in the paper.

4. In the cover paper, we noted that 6 out of the 7 "concerns" related to background section while a number of the comments made – most notably relating to the dynamic character of reserves and the Hubbert analysis – were unrelated to our paper as we (i) expressly recognised the dynamic character of reserves and (ii) did not use Hubbert analysis in our paper.
5. Following our response on each of the reviews (to be found on the ESD web site), we issued a revised version based on the comments made by the reviewers and a number of additional publications that had appeared in the literature. The revised version of our paper received one more round of comments by Scholz and Wellmer (Scholz and Wellmer, 2014), to which we responded in the form of an appendix (Edixhoven et al, 2014).
6. In their second round of review, Scholz and Wellmer made the following preliminary remarks, along with a number of additional comments. Here, they also indicated that they would issue a response paper on the ESD website in which they would comment on a number of statements/opinions/messages in our paper. Our paper was published in december 2014.
7. The current discussion paper contains the response by Scholz and Wellmer on our paper. It received two peer reviews thus far. The first reviewer is Michael Mew, who recently co-authored two chapters of a volume edited by Scholz and Roy and others (Scholz et al, 2014) which was published in the context of the Global TraPs project, including a chapter on PR reserves and resources which he wrote together with Vaccari, Scholz and Wellmer (Vaccari et al, 2014). Mew indicated that he broadly agrees with the position of Scholz and Wellmer in relation to granularity and the Moroccan reserves. The second reviewer wishes to remain anonymous. The second reviewer rather ardently made the point that the discussion paper attributes a number of errors to our paper which, in his view, are unrelated to our paper. See, for more detail, section 2.1 below.
8. For the structure of this review, reference is made to the table of contents in the cover page. For the references, please see our paper. The reference list below contains only those references not listed in the references in our paper, and does not list the various peer review documents, which can be obtained via the ESD web site as documents related to our paper.

2 THE DISCUSSION PAPER MISREPRESENTS OUR PAPER ON NUMEROUS ISSUES

9. As noted, a point strongly made by the second reviewer of the Scholz and Wellmer discussion paper, is that it repeatedly misrepresents our paper, both in the abstract and the body of the paper, while the title raises

the incorrect impression that the Scholz and Wellmer paper discusses our paper alone. This comment by the second reviewers relates in particular to the statements that we would have (i) ignored the dynamic nature of reserves; (ii) incorrectly applied or supported Hubbert analysis; and that we would have (iii) confused finiteness and staticness of available PR deposits.

10. I agree with the second reviewer that the discussion paper misrepresents the questions and the analysis in our paper on numerous issues including – but not limited to – those raised by the second reviewer. Section 2 discusses these issues. Section 2.1 discusses the various alleged errors which Scholz and Wellmer attribute to our paper. Sections 2.2 and 2.3 discuss that our research questions and our conclusions to them are inadequately summarized and misrepresented. Section 2.4 discusses that the discussion paper inappropriately frames our paper as sceptical/pessimist/neo-malthusian. Section 2.5 discusses that the peer review process of our paper is presented in an unbalanced manner in the discussion paper. Section 2.6 discusses that the title and abstract poorly relate to the contents of the paper, while the headers not always reflect the contents of the related sections.

2.1 SCHOLZ AND WELLMER ATTRIBUTE ERRORS TO OUR PAPER WHICH WE DID NOT MAKE

2.1.1 OUR PAPER DID NOT IGNORE THE DYNAMIC NATURE OF RESERVES

11. Scholz and Wellmer state that we would have ignored, or failed to have properly acknowledged, the dynamic nature of reserves. As noted by the second reviewer, this is evidently misdirected, as we specifically described the dynamic nature of reserves and resources in four different locations in our paper, including the section in the introduction where we discussed the peak P hypothesis (see below). As noted by the second reviewer, our paper did not "worry" about PR depletion. The scenarios which Scholz and Wellmer refer to were discussed in relation to how demand for may develop and included both high and low demand estimates. The discussion paper contains a number of extensive sections dealing with the dynamics of reserves. I agree with the first reviewer that these sections have no relevance and purpose in relation to our paper.

2.1.2 OUR PAPER DID NOT USE PEAK PHOSPHORUS/ HUBBERT ANALYSIS

12. Scholz and Wellmer state in the abstract, the introduction and numerous other places in the discussion paper that we would have failed to acknowledge the flaws in the peak phosphorus hypothesis and, again, devote extensive sections to this issue. They also submitted an Annex A which deals with the peak P hypothesis. However, as noted by the second reviewer, this criticism is misdirected as we did not use any Hubbert analysis in our paper. We also made this clear in our detailed response to the peer review by Scholz and Wellmer. What is more, in the introduction section of our paper (p. 492, par. 3 and 4), we explained the main flaw in previous peak phosphorus publications, which is that the modeling was based on USGS reserve estimates which, by their nature are dynamic and cannot be used to calculate the lifetime of all available PR deposits. This analysis is materially identical to the main comment which Scholz and Wellmer made in the discussion paper in respect of the recent peak phosphorus publications. See p.45 of the discussion paper:

"The major inconsistency of the "peak phosphorus in the near future" statement is that Cordell et al. (2009) used the USGS data of 15 GtPR of the 2008 reserves for an estimate of the URR. This certainly provides an underestimation of much more than factor 10."

13. It appears that Scholz and Wellmer's criticism is solely based on the fact that we used the words "hotly debated" to describe the debate peak P hypothesis (p. 44, line 1 and 16, p. 59 line 7-8). However, Scholz and Wellmer did not suggest to change these words when they had the

opportunity to make such suggestion during the peer review of our paper. While these words may not have been entirely adequately chosen, the analysis on page 492, par. 3 and 4 of our paper clearly demonstrates that – on this issue – our views are no different from those of Scholz and Wellmer.

14. Annex A contains another, related misrepresentation. Here, Scholz and Wellmer suggest that we misunderstood the commentaries on the Peak P hypothesis and that we would have concluded from these publications (Vaccari and Strigul (2012), Mew (2011), Scholz and Wellmer (2013), all of which are discussed extensively in our paper) that the criticism would have been based on the *quality* of the USGS data. The fact that we described the main flaw of the recent peak P publications in our paper disproves this.

2.1.3 OUR PAPER DID NOT "CONFUSE FINITENESS AND STATICNESS"

15. Another recurring statement is that our paper would erroneously confuse finiteness and staticness of the ultimate recoverable resources (URR). See: abstract, line 17, section 3.2, section header and p. 43 lines 11-22, and section 7.23 p. 62 lines 8-9, where they suggest that this error is typically made by "neo-Malthusians". Scholz and Wellmer, however, do not substantiate their statement or point out where exactly we would have committed this error. From a geological viewpoint, the world's PR deposits are fixed, or static. What constitutes a viable PR ore for mining, however, is dynamic, in the same way as reserves are dynamic. At this point, many low grade ore deposits or part of deposits are not entered in the resources, but this may change in the future due to changes in processing and economics. The dynamic nature of reserves and resources has been described in our paper. However, as aptly noted by the second reviewer, our paper does not discuss the URR of PR and I agree with him that this comment is misdirected in relation to our paper.

2.1.4 OUR PAPER DID NOT "ASK" FOR FIXED GLOBAL DRILLHOLE REQUIREMENTS

16. The abstract states that "*Edixhoven et al. ask for a differentiated inventory of world phosphate reserves including "guidelines which determine the appropriate drill hole distances."*, while the discussion paper repeatedly states that one of the main errors in our paper would include the "*the geostatistical naïve/unprofessional demand for fixed drilling plans to assess reserves*". However, we did not "ask" for such guidelines, but merely pointed out that the USGS classification requires detailed exploration for reserves (see in more detail, sections 3.1.4 and 3.2 below). In the section dealing with IFDC's restatement of the Moroccan reserves, we compared USGS/USBM drillhole requirements relating to certain US sedimentary deposits as a rough and additional indication that the deposits which Gharbi (1998) termed "reserves", would likely not qualify as such using USGS definitions. Based in a comment made by Scholz and Wellmer during the peer review, here, we also conveyed the uncertainty relating to the fact that these requirements were drafted for deposits in a different country.

2.1.5 OUR POSITION ON GRANULARITY IS NOT CORRECTLY REPRESENTED

17. On multiple places in the discussion paper, Scholz and Wellmer suggest that we would pose overly detailed requirements for the reserves or for global reporting.

An overly "detailed granularity" for a global assessment seems to be dysfunctional and naïve. Nevertheless, requiring transparency and compatibility of data is a meaningful suggestion [...].

18. That is not the point we made. Reference is made to section 3.4 of our paper (evaluation of IFDC's terminology proposals) where we stated:

For building a global long-term inventory of available PR deposits, a detailed classification appears required which enables "real" differences to be accurately stated (USGS and USBM, 1982) and

helps to prevent widely diverging resource estimates grounded in unclear terminology. To achieve global consistency, such resource terminology should preferably be compatible with UNFC. Discarding granularity altogether appears undesirable as this impairs comparability and transparency and, ultimately, jeopardizes the reliability of mineral resources assessments.

The USGS classification is such a detailed classification (see the quotation regarding "real" differences in the above fragment).

19. In the discussion paper, Scholz and Wellmer also appear to suggest that our paper proposes application of JORC criteria for USGS reserves. This is evidently incorrect as our criticism to IFDC's use of terminology was that it did not use USGS terminology. Moreover, in our paper, we noted that JORC style classifications are of little relevance for building long term inventories of PR (see, our paper, p. 498-498).
20. Referee Mew states, that "*[h]igh granularity demands high levels of detail in the data and runs risk of excluding deposits that don't meet that data.*" I do not agree with that. If a deposit cannot meet the requirements of a certain category in a classification, this can be expressed by classifying it in a lower class in terms of geologic assurance. That does not mean it cannot be classified and hence will be "excluded" from the reporting. It may, however, imply that a certain body of ore cannot be classified as a reserve.
- 2.1.6 OUR PAPER DID NOT IGNORE THE SOCIO-ECONOMIC NATURE OF THE CONCEPT "RESERVE"
21. On several occasions, the discussion paper states that our paper "ignores the socio-economic nature of the concept of a reserve". That is evidently not true; sections 3.2-3.4 discuss the various type of classifications in their socio-economic context.
- 2.1.7 WE DID NOT "SURMISE" THAT THERE WOULD BE LITTLE PR TO BE FOUND IN ADDITION TO KNOWN PR DEPOSITS
22. On page 39 of the discussion paper, Scholz and Wellmer state that we "surmise" (i.e: make a judgment about something without sufficient evidence; guess) that there would be little potential for further discovery in the geopotential field. Following that statement, they ask the rhetoric question why companies would spend large sums of money for exploration of ore deposits, if every deposit was already owned. This suggestion is misdirected. On page 495 of our paper, we explained that the potential for truly new major deposits (i.e. in addition to those deposits which are currently known but not entered in the resources) "*appears somewhat uncertain*". We based this, inter alia, on a statement by Van Kauwenbergh (2006) that oil exploration programs have probed most of the world's sedimentary basins and that any major new discoveries would have occurred in conjunction with these activities. We also pointed at a report by Smit et al. (2009) which, based on a personal communication by S. Jasinski, stated that according to USGS the discovery of major new deposits is unlikely. We also pointed at Sheldon (1987) and Scholz and Wellmer (2013a) who expressed contrary views. Both Van Kauwenbergh and Jasinski have occasionally assisted the authors with comments in the preparation of their work (See, acknowledgments Scholz and Wellmer, 2013a and the current discussion paper). I imagine that it would be not too much trouble to check these statements with their sources.
23. Meanwhile, the argument that companies would not spend fortunes in exploration if everything was already explored and owned by others, is fallacious in my view. There are many known deposits for which no mining plans yet exist and for which no permits have yet been granted, and which require further exploration to determine the viability of mining (Van Kauwenbergh, 2010).

2.2 OUR RESEARCH QUESTIONS ARE IMPROPERLY DESCRIBED AND TAKEN OUT OF CONTEXT

24. The research questions are discussed in section 2 of the discussion paper. The header of this section reads: "*The research question asked by Edixhoven et al. in the paper: are current data on phosphate reserves and resources sufficiently reliable?*" However, as noted, our paper contains three research questions, not one.
25. The first research question is whether the terminology proposals by IFDC, which entail a significant simplification of the USGS requirements, are likely to yield data which are reliable and comparable. In the discussion paper, this research question is described in half a sentence: "*Further, the paper criticizes the vague use of the categories reserves and resources.*" It does not specify who uses these categories vaguely (IFDC, see, our paper). In fact, the discussion paper does not even discuss our analysis in respect of IFDC's terminology proposals, but rather appears to suggest that IFDC used USGS terminology. However, the point is that IFDC substituted USGS definitions for reserves and resources and the related underlying requirements with its own, significantly more lenient definitions which do not have these underlying requirements (our paper, section 3.4). Our criticism was aimed at this simplification.
26. The second research question is whether it is common to report reserves as concentrate and whether the difference between PR ore and PR concentrate is sufficiently understood in the literature. In the discussion paper, this research question is reflected by the statement that our paper "*identifies some data in which phosphate ore and phosphate concentrate are not sufficiently distinguished*". Again, the paper does no justice to the importance of this research question. The area where our analysis matters the most – the various recent attempts in the literature to calculate an R/C ratio for ore resources; section 3.3.2 below – is not mentioned in the discussion paper.
27. The third research question is whether the restatement of the Moroccan reserve in the IFDC report is reliable and comparable and, most notably, whether the estimate meets the requirements of the USGS classification. This research question is described as follows in the discussion paper:

The paper by Edixhoven et al. discusses the classification and the data about phosphate rock by the USGS Mineral Commodity Summaries (MCS) (USGS 2010, 2014; see also Kelly et al., 2008) and, in particular, focuses on the increase of phosphate rock reserves from 15 GtPR in 2010 (USGS, 2010) to 65 GtPR (USGS, 2010). This increase is due mainly to the increase of the Moroccan reserves from 5.7 to 50 Gt PR, as reported in an IFDC Report (van Kauwenbergh, 2010) and "upward restatements by countries such as Syria, Algeria, and Iraq" (Edixhoven et al., 2014, p. 504). The paper questions whether these data meet "industry best practice" and are "reliable and comparable" (p. 493).

This fragment contains three incorrect representations of our third research question:

- (i) our paper reviews the IFDC report, not the USGS Mineral Commodity Summaries (MSC);
- (ii) it focuses on the increase of reserves for Morocco, which accounted for 100% of the increase of the reserves in the IFDC report relative and which reserves currently amount to 75% of the global PR reserves in USGS' MCS (USGS, 2015); the increases for Syria, Algeria, Iraq etc, were discussed in the context of research question 2 which deals with the difference between ore and concentrate.
- (iii) The quote relating to "industry best practice" does not relate to the data on Moroccan terms, but on the simplified terminology used by USGS (See: introduction of our paper, description of first research question).

28. As explained in more detail in section 3.2 below, our analysis in view of the third research question is not really discussed in the discussion paper.

2.3 OUR CONCLUSIONS ARE MISREPRESENTED

29. Our conclusions are summarized in an equally short paragraph of Section 2 of the discussion paper.

The paper offers the following conclusions: The estimates provided by the IFDC report do not present an “accurate picture” (p. 491). This is “mainly due to a simple restatement of ore resources as ore reserves” (p. 504). The simplified classification of using reserves and resources is considered to be insufficient, thus the IFDC report “provides an inflated picture of global reserves” (p. 491).

The paper suggests that the conclusion about the no physical scarcity in the coming decades is not reasoned or is “misleading” (see the title of the discussion paper). The paper finishes with a plea for “mineral resource reporting towards standardized definitions across the minerals, both to serve the needs of globalizing businesses and to allow for mineral availability studies within the context of sustainable development” (p. 503). Here, the use of UNFC (2010) classification, which has 40 theoretical cells (of which 12 respectively 14 are used) is proposed.

30. This section does not cover our conclusions as summarized in par. 2 above. I feel that this fragment should be amended so that it does, and so that the nature of the analysis which Scholz and Wellmer respond to is clear. In addition, the fragment quoted above contains the following inaccuracies:

- Our paper does not state that the IFDC report provides an inflated picture *because* the definitions it used are more lenient than those in the USGS classification. Rather, this conclusion is based on a number of OCP documents and a previous analysis by the author of the IFDC report (Van Kauwenbergh, 2006);
- Our paper does not suggest that “*the conclusion about the no physical scarcity in the coming decades*” would be unreasoned or “*misleading*”. In our paper, we made no predictions about future PR scarcity, and we certainly did not state or suggest that there will be any scarcity in the coming decades. Rather, we described on four separate occasions that reserves are dynamic; we noted in the introduction that there is no apparent risk of short term scarcity, and described a number of scenarios which all indicate that scarcity will not be imminent this century or significant time thereafter (see: background section of our paper);
- Our paper expressed no preference for the UNFC classification over the USGS classification in the context of long term reporting. We merely described the UNFC as a classification which makes it possible to compare the categories of the different classifications, both government type codes and JORC type investor codes (sections 3.3 and 3.4 of our paper). As also recognized by Hilton, the categories in the USGS classification can be easily mapped with UNFC (Hilton peer review to this paper). However, if the underlying thresholds for reserves in the USGS classification are abandoned, as IFDC did, such comparison is no longer possible.

31. In the discussion paper, Scholz and Wellmer state that they support the USGS classification. They express regret that the reserve base is no longer reported by USGS in its MCS. I agree. However, the whole point is that IFDC proposes not to use the rules of the USGS classification. The fact that IFDC uses the same terms as USGS – reserves and resources – does not imply that they mean

the same. This error occurs throughout the current discussion paper. See sections 3.1 and 3.2 below.

2.4 OUR PAPER IS INAPPROPRIATELY FRAMED AS SCEPTICAL/ PESSIMIST/ /NEO-MALTHUSIAN

32. Above, we discussed that Scholz and Wellmer incorrectly state that we use Hubbert analysis, make any predictions about future P scarcity and do not acknowledge the dynamic character of reserves. All of this is evidently incorrect and many the commentaries made in the discussion paper are evidently not related to our paper. Apparently based on these representations, Scholz and Wellmer frame our paper as Critical/ Sceptical and refer to Hilton as a source for this statement:

As may be taken from Hilton (2014), the paper by Edixhoven et al. can be seen as an example of a critical, skeptical contribution on the future availability of mineral commodities.

33. However, while Hilton certainly adopted a critical attitude towards our paper, he did not use the words "critical" or "sceptical". If the authors wish to frame our paper as such, they should do so in their own right. However, I do not think that doing so would be appropriate. The qualification as "sceptical" has the negative connotation that it departs from mainstream science (such as in "climate scepticism"). In the case of resource accounting, the mainstream appears to be that the USGS classification, and related classifications such as the UNFC, are proper instruments to classify mineral resources. This conforms with the position taken by us in our paper. Nor is there any basis to frame our paper as "pessimist" (versus "realist") or even "neo-Malthusian", as the discussion paper appears to suggest. All our paper does is to discuss the rationales and mechanics of major classifications, and review how current PR reporting in the IFDC report – and, to some extent, in USGS' MCS – conforms with these classifications. Our paper acknowledges the dynamic character of reserves and resources and makes no predictions about the lifetime of high grade deposits or the URR of phosphate rock.

2.5 UNBALANCED DESCRIPTION OF THE PEER REVIEW PROCESS OF OUR PAPER

34. I feel that the current discussion paper provides an unbalanced description of the peer review process. Scholz and Wellmer ignore the comments by the first reviewer, who endorsed our paper and strongly recommended it for publication. Also, Scholz and Wellmer omit to mention our response to their extensive review, which entailed that most of their comments were unrelated to our research questions and our analysis. Nor did the authors consider our response to Hilton's review, where we raised the point that he adopted the views by Scholz and Wellmer without considering our extensive response which we had posted on the ESD web site one month earlier. A similarly flawed description of the peer review process was provided in the 12th newsletter of the Global TraPs project (Global TraPs, 2014).

2.6 TITLE AND ABSTRACT DO NOT RELATE TO THE PAPER, HEADERS POORLY REFLECT CONTENTS

35. As noted by the second reviewer, the title and the abstract of the current discussion paper indicate that Scholz and Wellmer respond only to our paper, while the abstract refers to numerous errors which we did not make. I refer to the comments of the second reviewer, to which I agree.
36. In addition , the abstract contains the following statement: *The discussion suggests that the discrepant estimates of resource estimates that can be found in the literature are due to different system understandings, different conceptions of sciences, and diverging worldviews.*"This is repeated in the paper (p 35): *"We think that the question of why different scientists or stakeholders provide such different judgments about reserves and resources is of general interest. Thus, this comment*

discusses in Sect. 7 whether these frequently found discrepancies are due simply to (a) different data, system models, or system boundaries? Are there (b) fundamental reasons that are rooted in different conceptions or schools of sciences? Or can the differences be explained by (c) different worldviews?" While the titles of section 7.2 and section 7.2.1 suggest that they cover these issues, these sections in fact contain no discussion/ explanation at all why there are different interpretations of data; section 7.2.1 in fact it ponders on Hubbert analysis, elaborates on the (incorrect) suggestion that we would wish to require OCP to do more drillings, the restatements of Iraq reserves and a range of other issues unrelated to "system models", "worldviews" et cetera. The abstract and the pointer above should be amended in my view, as should the titles of sections 7.2 and 7.2.1. For completeness I note that the widely diverging estimates of PR in the past are discussed in our paper (section 3.2) in the context of the creation of the USGS classification, based on statements made at the time by USGS/USBM. According to USBM/USGS, the vast resource estimates were related to confusion over definitions. USGS/USBM also indicated that the USGS classification for PR was created precisely to help prevent such divergence. It would seem worthwhile to consider this rationale in the discussion paper.

37. In addition, a number of section headers do not seem to coincide with the contents of the various sections. Section header 1 ("*What knowledge do we have about phosphate reserves*") does not discuss this issue but merely attempts to summarize our research questions. The header to section 2 incorrectly suggests that our paper posed one research question (section 2.2 above). Section header 5.2 reads: "*International harmonization of the classification is meaningful*". The header does not specify which classification it refers to. Moreover, the section does not discuss harmonisation but attempts to explain the downward revisions of the Iraq reserves in USGS' MCS. Section header 5.3 reads: "*Mixing PR-Ore and PR-M may be avoided*". In fact, the the section is about the authors' attempt to show the relatively small impact of the PR ore and concentrate confusion on the global reserves (see, on that issue, section 3.3 below). Sections 7.2 and 7.2.1 of the discussion paper have been discussed above. Section header 7.2.3 reads "*The camps of sceptics/pessimists and optimists/realists should talk to each other*". This issue is not discussed in this section.

3 COMMENTS TO THE ANALYSIS BY SCHOLZ AND WELLMER

38. Below, I discuss the analysis in the discussion paper in relation to each of the three research questions and the conclusions in respect of these questions in our paper. Section 3.1 discusses the analysis in the discussion paper regarding our first research question (IFDC's terminology simplification). Section 3.2 discusses the analysis by Scholz and Wellmer regarding our third research question (the validity of the Moroccan reserves restatement by IFDC and whether it meets USGS standards). Section 3.3 discusses the analysis in the discussion paper regarding the PR ore and concentrate confusion, and discuss that an important aspect of our analysis in this issue is omitted.

3.1 IFDC'S PROPOSAL TO SIMPLIFY USGS TERMINOLOGY (RQ 1)

3.1.1 THE RESEARCH QUESTION

39. Research question 1 was about IFDC's suggestions to discard the granulation contained in the USGS system and replace it with two definitions which contain no further granulation. In the IFDC report, reserves are described as deposits which are currently economic, reported as concentrate, and resources as deposits which may become economic, reported as in situ ore (including the ore from which reserves are established). To place these simplifications into perspective, we reviewed the USGS, JORC and UNFC classifications. Our main finding was that discarding granulation and threshold criteria for reserves and resources, as proposed in the IFDC report, is at odds with each of the resource classifications reviewed. Our main concern was that the simplified terminology used by IFDC is inherently vague and yields unclear data

which is not comparable with data under the reviewed classification systems. We also expressed concern that the simplified terminology allows the individual analyst an overly broad discretion in determining which deposits constitute reserves or resources, rendering reporting of reserves and resources vulnerable to abuse. We noted that this may render data incomparable, a situation which the USGS classification aimed to prevent (our paper, section 3.1).

3.1.2 THE ARGUMENTS BY SCHOLZ AND WELLMER WITH RESPECT TO RESEARCH QUESTION 1 (SECTION 5.1)

40. As noted, Scholz and Wellmer do not expressly discuss our first research question and our related findings, but they do provide some related comments in section 5.1, entitled "*the constraints of granularity have to be considered*".) In very brief summary, their position appears to be as follows.

- (i) JORC reserves are more stringent than USGS reserves. This is because JORC codes are designed to meet investors' interests, which by nature are short term oriented.
- (ii) The USGS classification is a proper classification for the purpose of long term planning. The USGS classification has lower thresholds for reserves than JORC type investor classifications. The granulation of the USGS classification is better suited for global reserves reporting of PR as "*[o]ne is not measuring the thickness of a broomstick with a caliper at an accuracy of 0.01 mm.*"
- (ii) The reserve base, which is a part of the USGS classification but which USGS no longer reports in its Mineral Commodity Summaries, was a very valuable tool and offered the perfect granularity for long term resource assessment.
- (iii) A reserve base requires cost models. Due to lack of funding, USGS no longer is able to provide these costs models and, consequently, discontinued reporting a reserve base in 2009. Therefore, we have to make do with the remaining categories, reserves and resources.
- (iv) Other than our paper states, the USGS definitions reserves and resources are sufficient for long term reporting.

3.1.3 MAIN ISSUE IN OUR PAPER: IFDC DID NOT USE USGS UNDERLYING THRESHOLDS FOR RESERVES

41. When reviewing the arguments put forward by Scholz and Wellmer, it seems that, once again, our position is not adequately represented.

42. First, Scholz and Wellmer appear suggest that, according to our paper, IFDC should have used JORC style, investor based requirements to establish the Moroccan reserves. Our paper did not make such suggestion. In section 3.2 of our paper ("Financial reporting classifications") we noted that financial reporting classifications use stricter requirements than government type classifications such as the USGS classification and that reserves under JORC style classifications are therefore not fully comparable with reserves reported under government classifications. We mapped out the difference in the appendix to our paper, Figures S1 and S4 in the supplement to our paper. We also indicated that investor type classifications are blind to the long term perspective and therefore are less relevant for the job of creating long-term inventories of PR. Nowhere in our paper did we suggest that IFDC should have used JORC requirements for establishing reserves. Rather, as noted, we criticised IFDC for refusing to use USGS requirements.

43. Second, Scholz and Wellmer state that the USGS classification is appropriate for determining reserves. Also, Scholz and Wellmer conclude:

Taking the above framework conditions into account, it seems reasonable that the USGS distinguishes only two quantitative categories in its reports in the publication MCS: reserves and resources.

44. Scholz and Wellmer apparently assume that IFDC used USGS terminology in the IFDC report, or that the meaning of its simplified definitions of reserves and resources can be equated with the meaning of these terms in the USGS classification. This is not the case. In the IFDC report, IFDC took the position that the USGS classification, essentially, contains far too much detail to be practical in the context of a global reserves assessment. IFDC expressly stated that instead of the USGS definitions, it would use its own, simplified definitions. It defined reserves as PR that is currently producible, reported as extracted and beneficiated concentrate. Resources were reported as ore in situ, and defined as all PR that may be producible at some point in the future. However, using USGS terminology, the reserves are a rather narrowly defined class of resources which must both meet specified requirements in terms of the degree of geologic assurance and current economic viability. Given that Scholz and Wellmer accept that the USGS classification should be followed when determining reserves and resources, the question which needs to be addressed is: what are the requirements for reserves using USGS classification terminology and how do they relate to IFDC's terminology proposals? Unfortunately, this question is not considered in the discussion paper.

45. Below, I will first discuss the requirements in the USGS classification in terms of geological assurance (how well has a deposit been established). Then, I will discuss some issues relating to the economic reserves, including the desirability of a reserve base.

3.1.4 USGS RESERVES – REQUIREMENTS REGARDING THE DEGREE OF GEOLOGICAL ASSURANCE

46. As noted in our paper, the USGS classification uses three main concepts: resources, a reserve base and reserves. The reserves are the part of the resources which are geologically well established according to USGS thresholds and currently economic. For this reason, the reserves fluctuate constantly. The reserve base is a larger bracket of near-reserve resources from which the reserves are established, and which is less subject to short term price fluctuations.

47. The main geologic requirements for determining reserves in the USGS classification are described in our paper. Given that the USGS classification is a generic classification which for all minerals, specific requirements are needed on a commodity specific basis. For the US PR deposits, specific requirements were drafted (USGS/ USBM (1982)). In the USGS classification, in order to be entered in the reserve base, a resource must be Demonstrated, which requires that the deposit is either Measured or Indicated. See, definition of reserve base, to the extent relevant here:

The reserve base is the in-place demonstrated (measured plus indicated) resource from which the reserves are estimated.

48. Given that reserves are estimated from the reserve base under USGS requirements, this means that reserves, need to be Demonstrated, i.e. either Measured or Indicated. See, definitions of Demonstrated, Measured and Indicated:

Demonstrated.—A term for the sum of measured plus indicated.

Measured.—Quantity is computed from dimensions revealed in outcrops, trenches, workings, or drill holes; grade and(or) quality are computed from the results of detailed sampling. The sites for inspection, sampling, and measurements are spaced so closely and the geologic character is so well defined that size, shape, depth, and mineral content of the resource are well established.

Indicated.—Quantity and grade and(or) quality are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and measurement are farther apart

or are otherwise less adequately spaced. The degree of assurance, although lower than that for measured resources, is high enough to assume continuity between points of observation.

49. The USGS classification also recognizes "inferred" resource estimates, which are defined as estimates which are:

"based on an assumed continuity beyond measured and (or) indicated resources, for which there is geologic evidence. Inferred resources may or may not be supported by samples or measurements."

As noted in our paper, the USGS classification also uses the term "inferred reserves" and "inferred reserve base". In the IFDC report, it was suggested that inferred reserves are part of the reserves using USGS terminology. However, as noted in our paper (p. 497, footnote 3), this is not the case:

"Under the USGS classification, reserves are "the part of the reserve base which could be economically extracted or produced at the time of determination". The reserve base is defined as "the in-place demonstrated (measured plus indicated) resource from which reserves are estimated". Deposits with a lesser degree of geological assurance, such as "inferred reserves" form no part of the reserve base and, by consequence, are no part of the reserves. See also Fig. S1."

50. In our paper we noted that, in the absence of USGS' requirements for geologic assurance, a real risk exists that deposits are entered which do not meet USGS requirements. While Scholz and Wellmer have not discussed this analysis thus far, this terminology is relevant when considering whether the increase of the Moroccan reserves meets the requirements of the USGS classification (see, in more detail, section 3.2 below).

3.1.5 USGS RESERVES – ECONOMIC REQUIREMENTS

51. In addition to requirements in terms of geologic assurance, USGS reserves are based on economic requirements (feasibility of economic recovery). A point raised in the discussion paper is that it is regrettable that USGS discontinued reporting a reserve base on a per country basis in its MCS. I fully agree with that statement. In his review, Mew questions the viability of USGS' decision to do so. I also agree with that. As stated, the reserve base is a broader, more stable bracket of ore which border on being economically viable. The rationale is to provide a more stable inventory of a mineral resource, in this case PR, in order to allow longer term planning (USGS/USBM 1980). For this reason, while the requirements in terms of geologic assurance are identical to the reserves (see par 3.1.4 above), the cost requirements are set more leniently for the reserve base.

52. According to Scholz and Wellmer (2013a, see also the current discussion paper) the reason why USGS discontinued reporting is that its budget was cut and that it no longer had the financial means to continue providing costs updates with respect to the reserve base. However, reserves, being more subject to price fluctuations and economic developments than the reserve base, are in even more need for continuously updated costs assessments. If USGS lacks the funding for establishing costs criteria for the reserve base, this also casts doubt over her continued ability to update costs criteria for the reserves and restate reserves accordingly. We raised this point in the discussion version of our paper, where we stated:

It indeed is a well established principle under all classifications that economic thresholds should be updated from time (USGS, 1982, Camisani Calzolari 2006). The proposal [IFDC's proposal, JE] fails to recognize, however, that the reserve base was created to mitigate the effect of fluctuating prices, which impacts, or should impact, the reserves even more than the reserve base (USGS, 1982)."

In his review, Mew makes the same point and on this basis questions the viability of USGS' decision to discontinue reporting a reserve base.

53. The discussion of the reserves and reserve base category once more highlights that the reserve class is a rather narrowly defined resource category under the USGS classification. In order to classify as a reserve, a resource must meet specified thresholds in terms of geologic assurance and must meet the cost criteria as set by USGS. While it is not certain whether USGS in fact applies such cost criteria on a global scale, IFDC's proposal to discard such criteria altogether appears to impair the comparability of the assessments.

3.2 DOES THE RESERVE INCREASE IN THE IFDC REPORT PROVIDE A RELIABLE AND COMPARABLE PICTURE ? (RQ 3)

3.2.1 THE RESEARCH QUESTION

54. The third research question is whether the restatement of the Moroccan reserve in the IFDC report (which was subsequently accepted by USGS) is reliable and comparable. Our main conclusion was, based on numerous documents, that the single paper on which IFDC based its estimate of Moroccan reserves (1998) appears to offer an inadequate basis for IFDC' restatement of the Moroccan reserves. Our analysis in section 5.3 of our paper contains the following elements:

- The terms reserves and resources were notoriously jumbled in the literature concerning Moroccan reserves/resources at the time of the Gharbi (1998) analysis;
- Various OCP documents referred to the same ore bodies referenced in Gharbi (1998) as resources;
- Gharbi, in a previous paper (Gharbi and M'Chichi (1996)), referred to the same ore bodies as resources;
- Van Kauwenberg (2006) concluded previously, in an extensive analysis, that the term "reserves" was used in a rather loose way in Gharbi (1998) and that the term resources would probably have been appropriate. The IFDC report does not explain why it now reached an opposite conclusion.

55. As an additional rough indication, we also compared drillhole data for the Moroccan ore fields as provided in various OCP annual statements (the latest dating from the year 2000) with USGS drillhole requirements for some of the USGS deposits (USGS, 2982), which according to Scholz and Wellmer are of the same sedimentary type as the Moroccan resources (Scholz and Wellmer, first peer review response to our paper).

3.2.2 THE MAIN ARGUMENTS MADE BY SCHOLZ AND WELLMER IN RELATION TO THE MOROCCAN RESERVES

56. Section 5.4 of the discussion paper, entitled "*The Moroccan reserves are underestimated rather than overestimated*" contains the arguments put forward by Scholz and Wellmer in relation to the Moroccan reserves restatement. In this section Scholz and Wellmer do not discuss our analysis in relation to the third research question, nor do they discuss our arguments to the first research question which are equally relevant to this topic. Rather, Scholz and Wellmer make a number of statements the general message of which appears to be that there is much high grade ore contained in the Moroccan ore deposits. While this is true (we recognized this in our paper) it does not mean that all that ore can be accepted as a reserve. Below, I will provide my comments to some of these arguments made by Scholz and Wellmer.

- The conversion ratio between a cubic meter and a ton of PR ore would not be 2.0, as assumed by IFDC (Van Kauwenbergh, 2010), but rather between 2.0 and 2.5. This statement is not explained and requires a reference in my view.
- Scholz and Wellmer state that IFDC "*assessed the four phosphate rock regions to include approximately 170 Gt PR-M*". This is incorrect and should be 170 Gt PR-Ore. See Van Kauwenbergh (2010).

- Scholz and Wellmer refer to IFDC's statement that the unexplored extensions of the Khourigba and Gantour deposits are expected to contain very significant additional quantities of ore. While true, this statement is irrelevant in the context of reserve reporting as these deposits could not even qualify as an inferred reserve under the USGS classification. See, USGS/USBM, 1980: *"Postulated quantities of resources not based on reserve/reserve base extensions but rather on geologic inference alone, should be classified as undiscovered."* As noted in our paper, under no circumstances can undiscovered resources be classified as reserves using USGS terminology.
- Scholz and Wellmer state that the ore grades of the explored fields are exceptionally high and, on average, well above 30%. Grade numbers are provided in OCP (1989) The ore grades are as follows: Oulad Abdoun, 25.1-34.3%; Gantour: 22.9-32.9% P₂O₅; Meskala: 20.6-29.8% (not included in IFDC's reserve); West Sahara: 31.1-33.9%. These data do not seem to support the statement that the majority of the ore is "well above" 30% P₂O₅. This statement requires a reference.
- Scholz and Wellmer reference a personal communication by Mr. Terrab, the (former?) CEO of OCP, who apparently indicated to the authors that OCP had roughly estimated the costs for producing "far above the 50 Gt PR-M reported in the USGS-MCS." Scholz and Wellmer do not elaborate on the outcome of the costs estimate. Moreover, once again, the expectation that a certain ore body will become available as a reserve at some point in the future, does not signify that it should be termed a reserve now, using USGS terminology.
- Scholz and Wellmer state: *"In 1989, for instance, the OCP reported that 36% of the Khourigba, 18% of the Gantour deposit, and 56 Gt mineable reserves were explored (Savage, 1987) with a first estimate of 140Gt. These data obviously refer to PR-M (van Kauwenbergh, 2013)."* Scholz and Wellmer do not substantiate that the Savage data refer to marketable product rather than PR ore. The referencing is unclear as the Savage (1987) reference cannot refer to OCP (1989). The words *"first estimate of 140 Gt"* are unclear and should read: *"first estimate for the total resources of 140Gt, considering the unexplored extensions of the main deposits"* (see Savage, 1987). The statement that the Savage reserve number of 56 billion tonnes (56Gt) "obviously" refers to PR-M (PR concentrate), is not substantiated: the reference which is provided (Van Kauwenbergh, 2013) does not discuss this issue. Moreover, the statement is evidently incorrect in my view. Savage does not state that the estimate reflects concentrate. What is more, based on an estimated 36% exploration of the Oulad Abdoun (Khourigba) deposit and an 18% exploration of the Gantour deposit, Savage concludes that the "total resources are considerably greater and may approach 140 billion tonnes" (ie 140 Gt PR). Resources are by definition denoted as in situ ore. If Savage would thought that this estimate reflected concentrate, the total estimated resource number would have been much higher (see, the conversion rates for in situ ore in the IFDC report).

57. Scholz and Wellmer point out that the various parts of the Moroccan deposits are clearly "on different levels of the exploration ladder, and stress that the distinction of whether resources are demonstrated (measured and/or indicated) or identified (demonstrated and/or inferred) develops over time. Based on these arguments, Scholz and Wellmer conclude:

Against this background, the conclusion that "the increase of Moroccan reserves . . . was . . . due to simple restatements of ore resources as ore reserves" (p. 497) seems to be a very biased statement which is far from properly acknowledging the available data and the documented history of continuous exploration and mining activities.

58. I will revisit this statement in section 3.2.6 below.

3.2.3 DISCUSSION OF THE ARGUMENTS PUT FORWARD IN THE DISCUSSION PAPER

59. Our analysis on the Moroccan reserves restatement is mainly based on a significant number of documents described in section 5.3 of our paper. The main elements of the analysis are briefly summarized in section 3.2.1 above. This analysis is not discussed at all in the discussion paper. I will not repeat those arguments here but restrict myself to some additional comments.

60. In section 3.1, I discussed that inferred reserves are no part of the reserves under the USGS classifications. In the discussion paper, Scholz and Wellmer appear to recognize this. For instance, they state (discussion paper, p. 59 lines 18-19):

Reserves in the USGS MCS comprise the categories proven and probable reserves and measured and indicated resources (according to the JORC standard)

As noted in our paper, these categories overlap with USGS measured and indicated reserves. See figures 1 and 4 to the supplement of our paper, which maps the JORC reserve categories to the USGS reserve categories. Inferred resources form no part of these JORC classes. Both under JORC and USGS, resources must at least be Measured or Indicated if they are to be classified as a reserve.

61. The Gharbi (1998) paper on which IFDC based its reserves restatement, speaks of "réserves identifiées", or, identified reserves. While it is unclear which type of classification rules Gharbi used, under the USGS classification the term "identified reserves" is significantly broader than the term reserves. Under USGS terminology, the term "identified resources" aggregates demonstrated and inferred resources while the latter, as stated in our paper, form no part of the reserves under the USGS classification. While the IFDC report generally speaks of "reserves", the sections which discuss the Moroccan reserves refer to them as "identified" reserves or resources, consistent with Gharbi (1998) (Van Kauwenbergh, 2010).

62. On page 60 of the discussion paper, (lines 2-3) Scholz and Wellmer refer to the Moroccan reserves estimate in the IFDC report as an "inferred" estimate. Again, if this is true, this would signify that the estimate contains both demonstrated and inferred resources and, because of insufficient geologic assurance for part of the ore bodies, cannot be accepted as a reserve estimate using USGS definitions. This conforms with the analysis in our paper.

63. In the discussion paper, Scholz and Wellmer stress that, due to the dynamic character of reserves, inferred, identified resources may become demonstrated resources which may be entered in the reserve base (and, if economic requirements are met, in the reserves). While that is true, it does, once again, not mean that IFDC's reserves for Morocco can be recognized as reserves.

64. Here, it is useful to compare the USGS classification with the Australian Economic Demonstrated Resources (EDR) which USGS uses in its mineral commodity summaries for the Australian reserves (USGS, 2014, Appendix C sub A) and are methodologically comparable (our paper, section 3.1). As recognized in the discussion paper, inferred resources are not included in the EDR under the Australian classification (See, discussion paper p 39 which states that in 2013, the inferred resources were 2.4 times larger than the EDR.

65. The discussion of USGS' downwards revisions of the Iraq reserves is interesting, too. Here, Scholz and Wellmer describe the reasons why USGS downgraded the Iraq reserves (which were initially stated at 5,700 Mt PR ore in 2011) to a mere 430 Mt PR ore. According to Scholz and Wellmer this was done because the Moroccan ore had been classified according to the Russian classification, and it turned out that the vast majority of the ore bodies which had been accepted as a reserve under the Russian classification

did not meet the standards of the USGS classification. As explained in the discussion paper, with reference to Gert, 2007, the Russian classification recognizes four categories of reserves, the lowest of which are "inferred" reserves (class C2). It would be interesting to know how exactly the classes in the Russian classification relates to the USGS classification and exactly what considerations caused the very significant downgrade of the Iraq reserves in 2012.

66. Scholz and Wellmer appear to state that an *inferred reserve* of 50Gt PR may qualify as conservative (even though, as noted, inferred reserves do not qualify as reserves under the USGS classification. See, p. 60 lines 2-3: "*Based on this, an inferred estimate of 50 Gt PR-M may be judged as conservative.*" However, it is not established that all the Moroccan ore in the IFDC's reserves assessment reserves would qualify as an inferred reserve. After all, an inferred reserve would still have to meet the economic requirements for reserves, which means they have to be currently economically feasible for extraction. Issues relating to economic requirements under the USGS classification are discussed in some more detail in section 3.2.4 which discusses the analysis by referee Mew.

3.2.4 THE ANALYSIS BY MEW

67. Unlike Scholz and Wellmer, the first reviewer of the discussion paper, Mew, does contain a discussion of the various documents on which our analysis regarding the Moroccan reserves restatement is based. The comments made by Mr. Mew will be discussed in this section.
68. Mew questions the relevance of the question whether or not the Moroccan deposits qualify as reserves. Mew appears to consider this question little relevance to OCP because, given the dynamic nature of reserves, OCP may expect that resources will become reserves in the future. While the relevancy for OCP may be limited, the relevance from a scientific point of view is considerable. As explained on p 492 of our paper, while reserve data are less important for long-term planning purposes, it is nevertheless important that they are accurately stated. In the first place, accurate reserve data can be used for comparison while data based on unclear criteria cannot. Moreover, reserve data are still often used as a reference point for future PR availability. For instance, reserve data are used to calculate R/C ratio's and compare these with R/C ratios for other commodities, to reach conclusions about long term availability if PR. Reserve data are also used to analyze reserve growth. Moreover, as evidenced by the recent attempts to calculate an R/C ratio for the reserves, unclear terminology can lead to significant error in scientific analysis.
69. Mew states that, given the major change to industry economics (PR price changes) between 2006 and 2014, "*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'*". On this basis he concludes that "*[t]he realignment of Moroccan reserves suggested by the IFDC in 2010 is therefore not counter intuitive*". Later in his review paper, Mew explains that the most important factor here is the stabilization of the prices of marketable PR at over \$ 100 per ton since 2008, which is about 2/3 times higher than the level prior to the price spike. Mew states that "*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*".
70. The costs criterium for the reserve base as apparently still used by USGS was about \$ 100 per ton (Van Kauwenbergh, 2010). As noted in the IFDC report, this amount no longer appears viable for the reserve base (Van Kauwenbergh, 2010). Given that the current price is more or less equal to the cost threshold for the reserve base and that the geologic requirements for the reserve base are identical to the requirements for the reserves, one could assume that, based on current economics, a significant portion of the reserve base could in principle be entered in the reserves, depending on the degree of geologic assurance.

71. There appears to be some misunderstanding in Mew's analysis as to the size of the Moroccan reserve base which was last entered in USGS' reserve base in 2009. According to Mew (p.4) USGS' 2009 MCS (reporting on 2008) stated Moroccan reserves at 15 Gt PR and the Moroccan resources at 47 Gt PR, which entailed a reduction of 3 Gt each. One year later, when the reserve base was discontinued, the Moroccan reserve would, according to Mew, have been stated at 16 Gt PR in the USGS MCS. These numbers are not correct: both the 2009 and 2010 MCS reported Moroccan reserves at 5.7 Gt PR, while the 2009 MCS reported the Moroccan reserve base at 21 Gt PR. The numbers referenced by Mew are the global totals (USGS 2009; USGS 2010).
72. So, the Moroccan reserve base was last reported by USGS as 21,000 Mt PR in 2009, denoted as in situ ore. Based on the IFDC report however, the current PR reserves for Morocco are stated 50,000 Mt PR in USGS' mineral commodity summary, denoted as marketable product. This quantity is calculated from a PR ore resource of 138,000 Mt PR, which is more than six times as high as the reserve base prior to the reserves restatement and nearly three times as high as the global reserve base reported in 2009. Here, it should be noted that the information regarding the quantity of the Moroccan resources had been known to USGS since at least 1995, when OCP reported to Ms. Michalski that the aggregate "reserves" for the Moroccan deposits amounted 170,000 Mt PR. (Michalski, 1995, Jasinski, personal communication, 2014), and that this information did not cause USGS to consider such restatement back then. Here, one should also consider that reserves are not only based on economic requirements, but that generally accepted classifications such as USGS also pose the requirements relating to the degree of geologic assurance for reserve. Mew does not mention these requirements and does not appear to consider them in his review paper.
73. In our paper, we reviewed various OCP annual reports and noted that they all report the Moroccan ore bodies as resources. The oldest OCP annual report which we have been able to obtain dates from 1987. From 1987 upwards until at least 2000, the ore is reported as resources in the OCP annual reports. As noted by Mew, the years before 1987 reported the Moroccan deposits as reserves rather than resources¹.
74. In our paper, we noted the discrepancy between Savage (1987) and OCP (1989) which report the same numbers as cubic meters as are reported in the OCP annual accounts of the same period as cubic meters of ore. In our paper, we made no attempt to explain this anomaly. In his review, Mew indicates that in his view, much of the confusion can be traced back to the fact that – according to personal statements by OCP – *"on average, 1 m³ of OCP ore more or less equates to 1 tonne of PR-M"*. Here, Mew does not specify whether he refers to recovered ore or in situ ore. According to Mew, it would be *"clear from an analysis of various information sources that this conversion factor is used by OCP when presenting its own reserve/resource data"*. However, this theory appears unconvincing and rather speculative in my view, for the following reasons:
- (i) The rule of thumb that one cubic meter of ore yields one ton of concentrate may apply to the OCP ore which is currently mined. The ore to concentrate ratio compares reasonably well with the conversion rates in the IFDC report for much of the ore bodies which IFDC converted to reserves. However, there are different types of ore in the Moroccan ore deposits. For instance, the deposits contain large sections which require special treatment and for which, according to the IFDC report, an ore to concentrate ratio of 3,3 applies. A part of the ore has a higher carbonate content (IFDC, 2010). Therefore, it may be doubted whether the 'rule of thumb' presented here can be applied to the aggregate ore bodies of about 138,000 Mt PR which IFDC included in the reserves.

¹ Mew states that the annual reports from 1979 up through 1987 (with the exception of 1982) all report the ore as reserves, but this is not true for the 1987 report, which reports the Moroccan ore as resources.

- (ii) Moreover the theory which Mew posits as a fact finds no support in the documents on which he appears to base it, including Savage (1987) and OCP (1989), or Benchekroun (1984) and Belkhadir and Chaoui (1985) which were referenced as a source in the Savage and OCP publications (and of which no copy could be obtained). Rather, the contrary is true. In par 56, last bullet point above, I discussed a similar but unsubstantiated assumption by Scholz and Wellmer, based on Savage, 1987. As noted in that paragraph, the extrapolation of the undiscovered additional resources in the unexplored extensions of the ore bodies in Savage (1987) clearly shows that Savage took the numbers in Benchekroun, 1984 and Belkhadir and Chaoui (1985) to represent ore, not marketable product.
- (iii) Also, the OCP (1989) publication contains a specification of ore grades. This is not compatible to the notion that the overview reflects marketable product (see, footnote 4 of our paper, p. 502). Mew states he believes that OCP nevertheless intended to state a concentrate number and otherwise retained the characteristics of the ore. That, however, appears highly unlikely in my view.
- (iv) Here, it should be noted that the OCP publication appeared in Notholt et al (1989), which is one of the three volumes which appeared in the context of the UN Project 156. The volume is entitled "World Phosphate Rock Resources" and "*reflects the comprehensive efforts of Working Group 2 to organise geological data on all major world deposits and phosphate fields*" (ibid at xxiv). According to its title, the goal of the volume was to inventorize world phosphate *resources*. Apparently, the editors took special care that the publications made a proper distinction between reserves and resources². In this context, it seems rather unlikely that OCP would have wished to state a concentrate number here, or that the editors would have allowed this.
- (v) Finally, for completeness I note that the term "reserves" has been used both in documents which denoted the Moroccan ore in G m³ as in Gtons of ore (see Mew, describing the OCP annual statements over the years 1979-1986). For that reason, no conclusions can be drawn from the fact that the ore was apparently termed "reserves" in Benchekroun, 1984 and Belkhadir and Chaoui (1985), on which the numbers in the Savage (1987) and OCP (1989) publications were based.

75. The foregoing, obviously, provides no explanation why OCP underreported its PR resources by about 50% in OCP 1989 and certain preceding publications. The various documents discussed in our paper provide no explanation for this. Elsewhere in his review, Mew states – in another context – that the gradual increase of Morocco's resources between 1980 and 1990 occurred during a period of relatively low international PR prices and states that there would probably have been little incentive for OCP at that time to exaggerate its resource position, as this could "have potentially exacerbated the feeling that the market was in oversupply at the time". However, in the absence of conclusive information, one can only speculate as to the circumstances that caused these inconsistencies.

76. Mew appears to indicate that we are not qualified to make any statements about the Moroccan reserve restatements by IFDC because we do not qualify as "competent persons". The concept of a competent person stems from JORC style classifications where it is designed to protect investors against overly optimistic resource estimates. The concept is relevant within the boundaries and purposes of the classification in which it is formulated. IFDC, however, introduced its own terminology and does not adhere to any classification (Van Kauwenbergh, 2010) and I do not consider it to be of much relevance in relation to the IFDC report. The competent person requirement is discussed in more detail in section 3.2.5 below where I discuss similar statements by Scholz and Wellmer.

² See: Notholt et al (1989), who stated that: "*resource estimates for many countries and deposits often ignore the essential technical distinction between reserves and resources and offer insufficient data about the technical and economic feasibility of producing marketable grades of phosphate rock.*"

77. Mew indicates that, on the whole, he agrees with the appraisal by Scholz and Wellmer that our criticism of the change in the Moroccan reserve figure in the IFDC report is unjustified because:

OCP has clearly identified, through geological prospecting over several decades, more than 85 G m³ 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.

Mew's theory regarding OCP's "equating" cubic meters of ore with tons of marketable product has been discussed above. As noted, the data on which Mew appears to rely offer no support for this theory.

78. Mew recognizes that the ore assessments are at different stages of exploration, with a relatively small portion being explored "at a high degree of certainty and the remainder at progressively less detail". Mew appears to recognize that no real assessment has been made about the current economic viability of the aggregate ore bodies which IFDC recognized as a reserve. This is noted in the IFDC report as well. The report notes (p. 36):

"It is not known if all this phosphate rock is truly producible at today's costs and prices. There is no data to assess mining costs. Also, as mining proceeding into the Plateau des Phosphates, the ore may contain more carbonate requiring additional processing.

79. More importantly in this context, as noted before, the appraisal by Mew only discusses economic requirements relating to reserves assessment, but fails to discuss the requirements which apply in terms of geologic assurance, as discussed above. As explained above, the lesser degree of geologic detail constitutes an important limit when determining reserves. The fact that the lesser degree of geologic determination likely is of less relevance to OCP, given the size of its reserves, does not mean that such deposits can be recognized as reserves using commonly accepted resource classification criteria such as those stated in the USGS classification. The fact that OCP commands large resources of high grade ore, does not imply that all these resources can be recognized as reserves. Here, it is useful to compare Morocco's current reserves/resources ratio (50 Gt marketable PR reserves and 168 GT PR ore resources; last reported reserve base: 21 Gt PR ore) to the situation in the USA (1,1 Gt presumably marketable PR reserves³ (USGS, 2015) versus 40 Gt PR in situ ore resources (Van Kauwenberg, 2010) and a reserve base of 3.4 Gt PR extractable ore (USGS, 2009)). The USA, needless to say, is the home base of USGS so its data base for the US may be assumed to be more complete and reliable than its data base for Morocco. As noted in our paper, these ratios once again add to our analysis that, regardless of the future potential of the Moroccan resources, its reserves are currently significantly overstated in the USGS mineral commodity summaries.

3.2.5 THE COMPETENT PERSON REQUIREMENT

80. On p 50, line 1 and further, Scholz and Wellmer state that "the requirement of a competent person under the JORC code applies correspondingly to global reporting systems like that of the USGS". Scholz and Wellmer state that they explained this in more detail earlier in the discussion paper, but such is not the case. Scholz and Wellmer appear to suggest that the IFDC and USGS experts qualify as such and are best positioned to determine which information should be taken into account to determine which deposits are "reserves". I have a number of reservations with their use of the CP concept in this context.

³ Van Kauwenbergh (2010) notes that USGS has apparently been reporting PR as concentrate for significant time.

81. The term Competent Person is derived from the JORC code. Article 4 of the JORC code sets forth that it is based on three principles: transparency, materiality and competence. The principles of transparency and materiality relate to the quality of the report. The principle of competence requires that the report be "based on work that is the responsibility of suitably qualified and experienced persons who are subject to an enforceable professional code of ethics (the Competent Person)". Article 11 of the JORC code further clarifies that the CP should be a member of a professional organisation with a code of ethics and the ability to reprimand or expel members who do not live up to the standards set forth in the code:

A 'Competent Person' is a minerals industry professional who is a Member or Fellow of The Australasian Institute of Mining and Metallurgy, or of the Australian Institute of Geoscientists, or of a 'Recognised Professional Organisation' (RPO), as included in a list available on the JORC and ASX websites. These organisations have enforceable disciplinary processes including the powers to suspend or expel a member. A Competent Person must have a minimum of five years relevant experience in the style of mineralisation or type of deposit under consideration and in the activity which that person is undertaking

82. Unlike Scholz and Wellmer state, no standard exists for a CP for global reporting. The USGS classification does not use the concept. The initial, 1997 version of the UNFC contained a simplified definition of the CP. This definition was criticized for being "too vague to be of any practical significance", particularly because no mention was made of "any accountability or membership to a professional body with an enforceable code of conduct" Camisani Calzonari (1997). The current version of the UNFC no longer contains or reference to the concept of a CP. While I agree that introducing a CP concept for global reporting could be useful, in order for the concept to be meaningful, it should include requirements to safeguard transparency, materiality and reliability. If no requirements are posed in this respect, it will be devoid of practical meaning. Scholz and Wellmer go on to state:

"There can be no doubt that the USGS mineral commodity specialists responsible for their chapters in MCS and in the Minerals Yearbook as well as the IFDC experts have seen many phosphate deposits worldwide and are very experienced long-term ore deposit experts who can draw many comparisons between deposits under exploitation and those still not exploited, and can judge as best as possible which publicly available information should be taken into account for the category "reserves" and which falls into the category of resources."

83. That the USGS analysts could qualify as CP's in the context of the JORC classification, is not self evident because the USGS classification does not use the concept of a CP. Moreover, USGS no longer has the financials to determine the reserve base on a global basis, and apparently relies for reserve assessments on information provided by governments. Whether these data are verified according to the standards of USGS, is uncertain. As noted in our paper, it appears that this is not the case for at least a number of countries.
84. That the IFDC analysts would qualify as CP's within the meaning of the JORC classification, is even less apparent. As discussed, IFDC uses its own, simplified definitions, does not adhere to any resource classification and – to our knowledge – no other safeguards apply for maintaining transparency and materiality, such as membership of a professional organisation as discussed above. Moreover, even if a person would qualify as a CP, this would not imply that his findings could not be subjected to criticism. In the case of the JORC classification, this is clearly illustrated by the requirement that a CP be a person who is a member of a "professional body with an enforceable code of conduct". The statements that the experts of IFDC and USGS experts should be regarded as CP's (Scholz and Wellmer), or that I and my co-authors should not be regarded as such (Mew), appear to have little bearing on our analysis regarding Moroccan reserves and resources

3.2.6 THE ALLEGATION OF BIAS BY SCHOLZ AND WELLMER.

85. So, is the bias accusation made by Scholz and Wellmer in par. 5.3 of the discussion paper appropriate in view of our analysis? An allegation of bias may be justified in a situation where an author refuses to consider arguments which are contrary to his theories or preferences, all within the confines of the research questions and scientific issues at stake. One could argue that a research question by itself may constitute a bias. Such position has not been stated thus far. The first reviewer (anonymous) and the third reviewer (Cook) have endorsed our research questions. The second (Scholz and Wellmer) and fourth review (Hilton) did not discuss or criticize our research questions.
86. Furthermore, a bias could be present if a research omits to state or acknowledge material issues in the analysis of the research questions. The research questions which we posed are rather limited in scope. Our first research question was whether the terminology used by IFDC was a good idea. We concluded that it was not, because the terminology is not backed by the underlying requirements posed in the USGS classification and other major classifications and therefore inherently vague. We noted that this creates a serious risk that data generated by these definitions are not comparable to data generated through the major classifications. This is the third time now that Scholz and Wellmer comment on our paper, but they still have provided no real comments to this analysis.
87. The third research question was whether the analysis of the Moroccan reserves and resources was reliable and comparable with USGS reserve assessments. Thus far, Scholz and Wellmer have not discussed our arguments in relation to IFDC's Moroccan reserves restatement:
- (i) In their second round of peer review, Scholz and Wellmer did submit that the same statement which they now refer to, was biased because we would have failed to consider the ore to concentrate ratio's which the IFDC report applied for the Moroccan PR ore which it accepted as an ore reserve. We responded that our criticism was not aimed at this element of IFDC's analysis, but rather on the fact that they accepted an ore reserve on a very feeble basis (a single publication by Gharbi (1998)) ignoring, inter alia, that an opposite conclusion had been reached based a few years earlier in an analysis discussing the same publication by Gharbi.
 - (ii) In their first round of peer review of our paper the authors made a number of comments relating to our analysis of boreholes, without discussing our document analysis in relation to the Moroccan deposits. We made some amendments to express the uncertainty relating to the appropriateness of comparing borehole requirements for US deposits with borehole data for comparable deposits in another country.
88. This time⁴, the essence of the bias allegation seems to be that we did not discuss the potential of the Moroccan ore, which is obviously very significant. However, we described the magnitude of the Moroccan resources in close detail and acknowledged the dynamic nature of reserves, which entails that reserves can be promoted to be resources. We stressed that reserves, given their dynamic nature, are less relevant for long term planning than resources and deposits which may become resources in the future. The point we made is that the reserve increase for Morocco appears to be based on other standards than the USGS reserves, which impairs comparability and reliability. I believe that the "bias" statement is unwarranted. For completeness, I note that the statement is partly based on statements which are not correct (see, comments in section 3.2.3 above).

⁴ During the peer review of our paper, the authors accused our paper of bias because we would have supported the peak P hypothesis (which was unwarranted in our view), and because of our description of Global TraPs project (we stated, inter alia, that IFDC co-created the project while in fact it became co-CEO shortly after the inception, and we described the project as a network while it is in fact a research project).

3.3 IS THE DIFFERENCE BETWEEN PR ORE AND CONCENTRATE SUFFICIENTLY NOTED IN THE LITERATURE? (RQ 2)

89. The second research question and final issue discussed in this review, is whether the difference between ore reserves and reserves as concentrate is sufficiently understood in the scientific literature. Our methodology was to review the literature, including USGS' MCS and country reports, the IFDC report and Notholt et al (1989). We pointed out based on a multitude of documents and a detailed analysis that reserves for a number of countries in USGS' MCS are apparently reflecting ore, not concentrate. This has meanwhile been recognized by USGS, as also reflected in the discussion paper. Scholz and Wellmer state this is a valuable contribution of our paper, while Mew states the distinction should be used in all discussions on PR reserves/resources.

90. Scholz and Wellmer propose to use the abbreviation PR-Ore for ore and PR-M for marketable product/concentrate. Mew supports the abbreviations. However, while the term marketable PR appears preferable over the term PR concentrate (some PR qualifies as "direct shipping material" due to the specific characteristics of the ore; Van Kauwenbergh, 2010), I have some reservations with the term PR-Ore as it does not differentiate between in situ PR ore and extracted or extractable PR ore. The difference is relevant as mining losses will have to be taken into consideration when determining extractable ore. Therefore, my preference is to simply use the terms PR in situ ore, PR extractable ore and marketable PR, as has been done in this review.

91. In section 5.3 of their paper, Scholz and Wellmer point out that when looking at the aggregate world reserves as they are now reported by USGS, the effects of considering the difference between ore and marketable product are rather limited. That is stating the obvious, given that Morocco reserves – which IFDC denoted as concentrate – accounts for some 75 % of the global PR reserves in the USGS MCS (USGS, 2015). Whether the Moroccan reserve assessment meets USGS standards is a major question in our paper. On a per country basis, the differences are much more significant as testified by the ore to concentrate ratio for Morocco and South Africa as calculated in the IFDC report (reductions in volume of respectively, 63% and 86%, assuming 5% mining losses; see section 4.1 of our paper). Meanwhile, I feel that the authors are omitting to discuss the issue where it matters most, namely in the various recent attempts to calculate a resources to consumption ratio without considering the difference between ore and concentrate. This will be discussed in section 3.3.2 below. First, I will briefly discuss some methodological issues.

3.3.1 TECHNICAL COMMENTS REGARDING THE ANALYSIS IN SECTION 5.3 OF THE DISCUSSION PAPER

92. Scholz and Wellmer present a calculation based on Scholz et al. (2014, p. 48–53). This publication discusses "two estimates of recent mining efficiencies" (the authors presumably mean: "recent estimates of mining and beneficiation efficiencies), one by IFA (Prud'homme, 2010) and one by IFDC (VFRC, 2012). IFDC (VFRC, 2012) reports a more positive number than Prud'Homme (9,5%) but VFRC does not specify whether this relates only to the targeted ore or the ore in general. Here, it should be noted that German Geological Survey has a significantly less optimistic assessment and indicates that about 35% of the ore remains in the ground (Kippenberger, referenced in Scholz et al (2014) and in the discussion paper. The discussion paper takes the average between the Prud'Homme and VFRC assessments but given the above, one may wonder whether that is not too optimistic on a global scale.

93. Scholz and Wellmer point out that the "*beneficiation efficiency is higher for magmatic phosphates producing phosphate concentrate with more than 30 %.*" While this is true, the beneficiation

efficiency is poorly unrelated to the loss of volume which occurs in beneficiation. It is the loss of volume that is relevant in this calculation (see our paper, section 4.1).

94. Scholz and Wellmer state that *Geoscience Australia (2014) reports that the Accessible EDR contains 213 Mt of P₂O₅ which, taking the average of 30% P₂O₅ for PR-M would result in 0.71 Gt PR-M instead of 0.87Gt in the USGS MCS. This is not correct however. According to Geoscience Australia (2014) the ("EDR of contained P₂O₅ in 2012 was unchanged from 2011 at 148 Mt.").*
- The 213 Mt referenced by Scholz and Wellmer refers to the P₂O₅ content of the total demonstrated resource, of which 65 Mt (31%) is classified as paramarginal (Geoscience Australia, (2014)). Adopting the methodology employed by Scholz and Wellmer, this would result in 0.49 Gt PR-M, rather than 0.71 Gt PR-M.

3.3.2 THE DISCUSSION PAPER OMITTS TO DISCUSS THE ORE AND CONCENTRATE CONFUSION WHERE IT MATTERS MOST

95. As indicated, my main comment to section 5.3 however is that it posits the ore/concentrate as an issue with relatively small impact, while omitting to acknowledge and describe the issue where it matters most, namely the various recent attempts in the literature to calculate a static resources to consumption ratio. Reference is made to section 4.3 of our paper, where we pointed at publications by Vaccari and Strigul (2012), Mew (2011) and, most notably, Van Kauwenbergh et al (2013). Each of these publications attempted to calculate a static resources to consumption ratio, ignoring the difference in tonnage between in situ ore (in which the resources are denoted) and PR. On this basis, Vaccari arrived at a static lifetime for resources of 2000 years (but included the reserve tonnage in the resources); Mew arrived at a static lifetime of 1000 years (considering a static consumption of 250 Mt marketable PR per year). Van Kauwenbergh et al concluded, based on a static consumption of 210 Mt PR per year, that "the world has over 1400 years of resources". The latter publication was rather remarkable given that the difference between ore and concentrate had been carefully considered in the IFDC report. In our paper, we commented that each of these static resources to consumption ratio's presents a grossly inflated picture as the reduction in volume associated with the beneficiation process was not considered. As noted, the IFDC report arrived at a 63 % reduction for the high grade Moroccan resources. Much of the world's resources is significantly lower in grade, and according to Notholt et al. (1989) perhaps 2/3 of these resources have a high carbonate content (Notholt et al (1989) p xxiv) which requires additional processing and, consequently, additional losses. Obviously, beneficiation techniques are likely evolve, but the difference is nonetheless rather important. It should be noted that these are not the only publications in which this error occurred. In the recent report of the Global Partnership on Nutrient Management, contains the same error:

In this context, it is relevant to distinguish the terms used. The term 'reserve' represents the currently economic and accessible fraction of the total resources. By contrast, the term 'resources' refers to total estimated amounts, that are in-principle feasible for extraction according to current technology and concentrations. In the case of phosphate rock, world resources are estimated at 300 billion tons (U.S. Geological Survey, 2012a), approximately 4 times the estimated reserves. Subject to future economics and accessibility, at present rates of production, the currently estimated global phosphate resource would have an estimated lifetime of around 1500 years. Further exploration in future, combined with improved and more cost-effective technologies, would be expected to increase both the estimated reserves and resources.

This report was co-authored by Mr Scholz and has received contributions from Mr.Roy, the CEO of Global TraPs and other persons affiliated to the Global TraPs project. In previous publications, Scholz and Wellmer raised the point that "wrong" data may have political impacts they may have (Scholz and

Wellmer, 2013a). The same, however, appears to these messages and I feel that the discussion paper should acknowledge this more clearly.

96. In the section 4.3 of our paper, we also raised comments about a 3000 year extrapolation by Scholz and Wellmer (2013) of the Western Phosphate Field (WPF) in the USA which ignored the difference between ore and concentrate. Here, Scholz and Wellmer also noted that this was obviously too optimistic but that a 1000 year static lifetime would seem reasonable. In our paper we pointed out that this could still be too optimistic in view of the depth at which the vast majority of the WPF ore is located (up to 9 kilometer depth) and the tectonic disturbance which occurred throughout the WPF. During the peer review Scholz and Wellmer explained a number of the assumptions on which they based their estimate⁵ but also acknowledged that they were not aware of the depths noted by in our paper and acknowledged that the "depth considerations may be critical". In the discussion paper, Scholz and Wellmer state that they provided the arguments for a 1000+ years static lifetime for the WPF, but omit to mention the depth issues. I feel this should be mentioned as well. After all, as noted in our paper, it is desirable that both the opportunities and limitations of a deposit are adequately stated.

⁵ For instance, Scholz and Wellmer (2014) pointed at the fact that there are waste shales containing lower grades of ore not considered in Moyle and Piper (1993) which may become available for mining; this is correct. Scholz and Wellmer also indicated that the tonnage reported in Bauer and Dunning (1979) is somewhat higher than the tonnage reported in Moyle and Piper (1993). Here, it should be noted that the Moyle and Piper estimate is based on Sheldon (1989) and that the Sheldon (1989) estimate is, in turn, based on Cathcart, Sheldon and Gulbrandsen (1984). The Cathcart, Sheldon and Gulbrandsen report (USGS Circular 888) is a comprehensive overview by USGS of phosphate rock resources of the United States. The report contains a detailed comparison of the various estimates of the Western Phosphate field and discusses the Bauer and Dunning (1979) report, the Krier and Gulbrandsen (1980) and several other reports relating to the WPF. The numbers mentioned in it, repeated in Sheldon (1989) and Moyle and Piper (1993), appear to reflect the authors' best estimate of the data provided in the various studies which they reviewed, taking into consideration methodological issues. In addition the Cathcart, Sheldon and Gulbrandsen report raises a methodological issue which results in an overestimation of the higher grades in the Bauer and Dunning report (Cathcart, Sheldon, Gulbrandsen, 1984, p. 29).

