

SUPPLEMENT TO THE SECOND REVIEW

INTRODUCTION		
	Scholz and Wellmer:	Response
1	<i>The authors deal with the lack of transparency, consistency and validity of key data of reserves and resources. Though this intention is valuable and the paper nicely deals with the difference between “government reporting classifications” (p. 1014) and financial reporting (p. 1015), the paper insufficiently acknowledges the function that different classifications may have for certain questions and actors such as consumers which are interested in short-term supply security, mining companies or lending institutions which are interested in the lifetime of a mine, or governmental actors who take responsibility for different long-term societal resources security (see C1, below).</i>	<p>Chapter 3 discusses three types of classifications in the context of the first research question: is the simplified terminology employed by IFDC compatible with leading resource classifications? This chapter discusses the function of different classifications: it explains that governments have an interest in both short term and long term strategic planning; that the (governmental) USGS classification is aimed at enabling commercial and long term public planning and that the strength of these classifications is that they allow both an analysis of those deposits which are or nearly are economic now and those who may become so in the future, when economics and technological development so permits. We discussed financial reporting classifications and explained that these classifications are aimed at providing transparency and providing correct and reliable data to the investing public. We explained that these classifications have a more narrow focus, which inheres in the fact that mining corporations and financial markets by their nature are only interested in reporting deposits which are economic within a time frame appropriate for investment, and that such classifications are therefore blind to the long term perspective. We also discussed the UN Framework Convention, which aims to be compatible both with JORC style financial classifications and government classifications and strives to further transparent, uniform and comparable reporting both for financial and governmental purposes. We concluded that there is a gradual global movement towards more uniform resource classification and that IFDC's proposal to discard any granularity relating to resources and reserves terminology is at odds with each of the classifications we reviewed.</p> <p>We feel that we adequately discussed the rationales for and differences between the various classifications we reviewed, to the extent relevant for first research question. We believe that expanding on these issues further would distract from this research question and would not improve the quality of the paper. The reviewers made certain comments which would improve our paper and which will be incorporated in it. This will be discussed below.</p>
2	<i>The Edixhoven et al. paper is neither (yet) an “in-depth literature review” nor does it adequately presents the issue of “recent revisions of phosphate rock reserves and resources” as the title suggests</i>	<p>The first reviewer commented that the paper uses thorough referencing. Indeed, we believe it is appropriate to say that the paper is in-depth in the areas which deal with the research questions. However, the reviewers do not discuss the research questions and hardly discuss the analysis we presented in respect of these questions. Instead, the reviewers mostly dispute fragments from the background section and the problem statement and do not always reflect the discussion in a balanced manner. This will be addressed where appropriate below.</p> <p>The reviewers do not substantiate that the paper would not adequately present the issue of “recent revisions of phosphate rock reserves and resources”. In fact, the reviewers discuss only fractions of our analysis in this respect.</p>
3	<i>In particular, the paper does not reference many important recent papers devoted to this subject. Thus it presents results from Hubbert curve applications and misses the discussion about adequate and</i>	<p>To our knowledge, there have been no papers published that have dealt with the revisions of global PR reserves and resources. What the reviewers apparently mean to say is that we did not devote attention to peak P discussions etc. We would have missed a number of rebuttals of "peak P" discussion ((i.e. Vaccari and Strigul, 2011, Mew, 2011 and Scholz</p>

	<p><i>inadequate applications of this method (see C2).</i></p>	<p>and Wellmer, 2013¹) and yet rely on findings obtained from papers in which the peak P hypothesis was presented.</p> <p>In our paper, we did not rely on the findings of Peak P but merely mentioned the discussion as background information. The reason why we identified the peak phosphorus hypothesis was because the IFDC report was issued partly in response to these papers (Van Kauwenbergh (2010a) p. vii). Peak phosphorus formed no part of the research questions, was not among the keywords submitted with the paper and has already been described extensively in the literature. For completeness, we note that we cited each of the abovementioned articles in which peak phosphorus is rebutted, albeit in another context.</p> <p>To address this comment, we will include references to these papers in relation to peak phosphorus as well and add a few lines to signal the discussion in more detail.</p>
4	<p><i>For the reviewers, the biggest flaw is the insufficient incorporation of the dynamics which is linked in any quantitative estimate of reserves and resources. This led to an improper use of the concept of lifetime (C3). The paper acknowledges that reserves and resources are dynamic (page 1011). However, the authors do not draw the correct conclusion because the evolution of the interaction between societal demands, technology development and available/depleted resources is not properly acknowledged. There is no doubt that on the supply side the discovery of and/or production from new deposits including the improvement of recycling rates will take place as demand increases and phosphate reserves may become smaller (Scholz & Wellmer, 2013).</i></p>	<p>A major tenet of Scholz and Wellmer is that reserves and resources are dynamic; that new deposits will be discovered while efficiency gains will allow for lower grade deposits to be mined (see this review and Scholz and Wellmer, 2013). The criticism that we would have insufficiently incorporated this in our paper is the centre piece of the review and large parts of the reviewers' "concerns" (1) and (3) expand on this. However, this alleged "biggest flaw" bears no relation to the research questions. These questions are (i) whether IFDC's use of terminology has sufficient safeguards for gathering reliable and transparent data; (ii) whether the difference between ore and concentrate is sufficiently understood in the literature and (iii) whether the increases of reserves and resources are reliable, focusing on Morocco. In fact, this criticism by the reviewers refers only to certain elements of the background section (See our response to C3).</p> <p>Moreover, this critique is without merit in our view. We recognized on a number of places in the paper that reserves and resources are dynamic. Moreover, we did not present any view on longevity of PR deposits (we did not, properly or improperly "use" the concept of lifetime). We merely described a number of papers in the background section which deal with potential depletion rates in environmentally reactive scenario's, to highlight the need for reliable data on PR reserves, resources and those deposits which humanity may come to depend on when currently recognized reserves and resources will have been depleted. See our response to comment C6(1) below.</p>
5	<p><i>The paper is similar to many papers that have been written on near future phosphate rock scarcity because it refers to a static reserve concept and ignores both, i.e. how reserves depend on the technology and on the amount of money society is willing or forced to pay for something</i></p>	<p>This observation is incorrect on both counts. To our knowledge, there have not been any other papers providing an in-depth analysis of the IFDC data and the major recent revisions of PR. Moreover, it is obvious that the paper does not refer to a "static reserve concept". We have highlighted this in a number of places. For instance, our paper stated:</p> <p><i>Given the economic function of resource classifications, reserves and resources are dynamic. Sub resource deposits, termed "occurrences" (USGS) or "other quantities in place" (UNCF), form no part of the resources, but may become so as prices rise or as technique evolves (USGS, 1980; Cathcart et al., 1984; Herring and Fantel, 1993).</i></p>

¹ In our paper, we cited this paper as Scholz and Wellmer, 2012. However, the reviewers cite it as Scholz and Wellmer, 2013. We will change this reference throughout the paper accordingly.

		<p>See also our conclusions:</p> <p><i>A truly independent and scientifically sound global inventory of PR deposits, as envisaged in the report, is yet to take place. Such review would also need to realistically assess those deposits which are not currently viewed as resources and which humanity will come to depend upon once today's reserves and resources are depleted.</i></p> <p>To assess whether "humanity is on the safe side", as the reviewers do (see their comment in section C3(8) below), it is essential to have transparent and reliable data as to known PR deposits and their potential. If one wishes to use the R/C ratio as a warning indicator, as the reviewers do, one should have reliable information as to reserves as well. This data transparency is what our paper is about.</p>
6	<p><i>The current history of phosphate mining and resources is characterized by an increase of phosphate reserves (measured by phosphate rock concentrate) providing a higher abundance than most other minerals and metals (C4).</i></p>	<p>Other than the reference to C4 suggests, the reviewers do not discuss this issue in the context of "Concern 4".</p> <p>PR reserves have increased at certain intervals in the past but have essentially remained constant during the last 20 years (Van Kauwenbergh, 2010a, page 31). The last few years have seen an increase of reserves which in part are due to further exploration. However, the critical question asked in our paper is whether the main increases are reliable. Again, our analysis is hardly discussed.</p> <p>Resources in the IFDC report are higher than reported in the context of the UNESCO/ IGCP Project 156 (Notholt et al (1989)). We note that this is in part due to the fact that Moroccan resources appear to have been understated by 50% in OCP (1989), which publication is a chapter of the second volume of Project 156, Notholt et al (1989), and in part due to increased exploration of the Moroccan resources. See for more detail, sections 5.1 and 5.3 of our paper.</p> <p>The reviewers do not explain whether their assessment of abundance of PR is in absolute terms or in relation to actual or anticipated demand. This statement requires a clarification.</p>
7	<p><i>It is irritating that the reviewed paper includes stories between the lines which may create incorrect impressions that IFDC and also USGS have undertaken activities to safeguard high estimates of reserves in Morocco or to "silently" correct mistakes (p. 1022, l. 19) of high estimates.</i></p>	<p>Chapter 5 of the paper is devoted to the restatement of Moroccan reserves by IFDC. The analysis in this chapter is thoroughly referenced and explains on the basis of numerous documents how Moroccan reserves and resources evolved in recent history. Chapter 5 explains that the deposits identified in Gharbi (1998) as "reserves" should in all likelihood be classified as "resources". This is hardly a "story between the lines" and we believe this should have been discussed more extensively than was done in the review. Reference is made to our comments to C 4 (10) below.</p> <p>The comment regarding USGS relates to an update by USGS in its 2012 MSC (USGS, 2012), in which deposits in Iraq were restated from zero to 5 800 Mt PR (more than the reserves of the US and China combined). The USGS country report for Morocco (Taib, 2010) explained this was based on "discoveries" made by USGS. This report did not mention that a very significant part of these deposits had actually been described as resources decennia earlier (Al-Bassam, 1989). See for more detail our response to comment C 4(4) below. The next year, USGS downgraded the Iraq reserves to 430 Mt PR which is the ore reserve of the only operating facility in Iraq. We will delete the word "silently".</p>

8	<p><i>There are other flaws, such as an obviously wrong assessment of the increase of phosphorus demands caused by biofuel production (C6) owing not incorporating recycling streams</i></p>	<p>Biofuels were mentioned in the background section as one potential driver for future PR consumption. Here, we cited a few publications which deal with possible future PR consumption extrapolations, including a scenario analysis based on the UN millennium assessment scenario's (Van Vuuren et al., 2012). We included the potential role of biofuels in our suggestions for further research. We respond to this comment below, where discussing the reviewers' "Concern 6".</p>
9	<p><i>It is valuable to stress that with respect to classification, the question of why certain data for minerals, metals or commodities are generated is insufficiently explained (see p. 1014-1015).</i></p> <p><i>Any data and classification of resources is functional (i.e. serves to answer certain questions). Data collection has significant costs associated with its generation and represents a valuable good for companies. We should acknowledge that a different graininess/granularity or scale of time have to be linked to classifications and data for different stakeholders, though, as noted in the Edixhoven et al. paper, consistency and transparency of classification should be the aspiration.</i></p>	<p>The paper explains why data are generated in the context of research question 1 (chapter 3). See the response comment 1 to the introduction, above in this supplement. This research question addresses whether the proposal to disregard any granulation in the IFDC report is in line with generally accepted principles in resource classification. The reviewers do not discuss this research question or its validity.</p> <p>The reviewers make two points here, both of which have been discussed in chapter 3 of our paper.</p> <p>The first is that data collection involves significant costs. Even though the reviewers do not specify this, it appears that they refer to the costs of exploration here. We note that one of the points for maintaining granulation is to prevent that deposits which are insufficiently explored will be reported as reserves, even though they may become reserves when more exploration is done. While significant costs are associated with the exploration and economic analysis to establish reserves, the costs of appropriately entering deposits in a detailed classification system such as UNFC have not been mentioned as a significant issue in any of the publications we reviewed. See, in more detail, comment C4 (7) below and our response to that.</p> <p>The second point is that different classifications have different purposes for different stakeholders. This is true and has been explained in our paper as well. One comment which the reviewers make is that JORC style classifications maintain an even greater granulation than the USGS classification and other government style classifications as governments may look only at economic and mining "modifying factors" and not at legal, social or governmental factors. This is a valuable contribution and will be incorporated in the paper, as will be discussed in more detail in our response to comment C 1 (8) below.</p>
10	<p><i>Finally, minable non-renewable resources on earth do not have the character of a fixed pie which is presented on a table and which is eliminated if the pieces are eaten (C7). The authors apply an inadequate oversimplified rationale of the management of resources.</i></p>	<p>The reviewers explain this argument in the context of "Concern 7". Reference is made to our response to this section of the matrix.</p>
11	<p><i>In order to allow for understanding certain arguments and conclusions of the reviewed paper, the reviewers provide a list of concerns (C1-C7). For each concern, some statements of the paper are noted in italics followed by arguments why the reviewers think that the reviewed statements and conclusions are wrong or do not</i></p>	<p>As set out in our response, a scientific review implies that one reviews whether the research questions are appropriate and have been properly addressed. The review does not discuss the research questions and hardly discusses our analysis in respect of these questions. Only "Concern 4" contains some discussion of elements our research questions 1 (IFDC's proposal to discard granulation) and 3 (the Moroccan increase of reserves). We refer to our response to C4.</p>

	<i>meet science-based state of the art knowledge</i>	Six of the seven "concerns" relate to statements in italics which are all taken from the background section and the problem statement. These quotations are often incomplete and the review often does not adequately reflect the discussion in our paper. This will be explained in more detail where appropriate below.
12	<i>There is a broad range of issues which are presented in a biased and incomplete manner</i>	<p>The word "bias" is used in respect to two issues:</p> <ul style="list-style-type: none"> - Scholz and Wellmer submit that our paper is biased because it refers to the peak phosphorus hypothesis without taking into account that this hypothesis is disputed in the literature. See our response to comment 3 to the introduction above and, in more detail, our comments to C 2(1). - We would have described Global TraPs in a biased manner, stating that IFDC created the Global TraPs project while it was in fact initiated by Mr. Scholz, representing science. This is indeed correct and we will reflect that in the paper. Scholz and Wellmer also state that it is wrong to present the project as focusing on the supply chain. According to its newsletters, the project initially was supply chain oriented but the scope of the project was apparently broadened. We will edit the paper to reflect this. See our comments dealing with "Concern 5" below). <p>The bias on "a broad range of issues" is not substantiated any further.</p>
13	<i>Resources management is a genuine interdisciplinary field. However, we have to acknowledge that an analysis of this field does not only require the consideration of aspects of geologic, technological, natural sciences but also social sciences and even aspects of humanities such as social justice. A thorough analysis of the reality of reserves and resources management also asks for knowledge about insights from the practice of exploration, mining and resources management.</i>	<p>The reviewers appear to suggest that any paper dealing with P deposits needs to be interdisciplinary in order to consider a broad range of issues including geologic issues, natural sciences, technological knowledge, social sciences and even aspects of humanities. Our paper expressly does not deal with such broad ranges of issues but is limited to the three research questions as set out in the paper and our response to comment 4 of the reviewers' introduction.</p> <p>We believe that one can validly analyze aspects of data reliability in isolation from the general debate on "the realities of resource management", particularly if there already are papers describing such generalities (such as Scholz and Wellmer, 2013). If the opposite were true, a critical and detailed review of any issue would not be possible.</p> <p>An analysis of data reliability may require no more than a review of data sources to see if they are properly interpreted. In the case of the IFDC report, where resource classification definitions are simplified, it is also appropriate to review whether these simplifications are in line with current practice in major classification systems. This, also, does not require a description of the entire context as identified here by the reviewers.</p>
	C1 Not only the dynamics of the demand side, but also that of the supply side (including reserves) have to be acknowledged; the supply-demand interaction matters	
	<u>Scholz and Wellmer</u>	<u>Response</u>

1	<p>Citation concern 1: <i>"Given the near total dependence of food production on PR (phosphate rock) data on PR deposits must be transparent, comparable, reliable and credible. (p. 1006)</i> <i>Due to various factors such as population growth, more phosphorus intensive diets (meat and dairy), and an increasing use of bio fuels, PR consumption is expected to increase significantly further over the next century (USGS, 2013). (p. 1007)"</i></p>	<p>The reviewers subscribe to the first statement ("<i>Certainly the reviewers agree with the first statement as an important goal</i>") but do not, or hardly, discuss the analysis which we presented in this respect.</p> <p>The second line is almost literally derived from a commodity review by USGS. This fragment is neither "wrong" nor is it clear that it would not meet "science-based state of the art knowledge".</p>
2	<p><i>Certainly the reviewers agree with the first statement as an important goal. The authors, however, do not seem to realize the reality in the geologic world, the nature of the reserve data available in the world, which can always only be a snapshot in a dynamically developing resource world. The authors acknowledge the dynamic nature of reserves and resources (p. 1011, line 4), but do not draw the proper conclusion.</i></p>	<p>As acknowledged by the reviewers, we recognized that reserves and resources are dynamic (see comment 5 to the introductory statement).</p> <p>The reviewers do not clarify what they think our conclusion is and do not elaborate why it would be improper. In fact, we stated no conclusions in respect of the longevity of PR reserves, but merely highlighted various consumption extrapolations and scenario's, part of which are significantly higher than the static consumption rate applied in the IFDC report. This will be discussed below in response to "Concern" 6.</p>
3	<p><i>To understand the character of reserves, one has to understand the total resource box, which covers everything which is available on Earth: reserves, resources and geopotential (see Figure 1)</i></p>	<p>Instead of discussing our research questions, the reviewers include a multiple page section in their review ("Concern 1") which is in fact a repetition of the their views set forth in Scholz and Wellmer, 2013. The entire section does not include a single reference to the paper it discusses. We believe that this section of the review is redundant. We explained the difference between reserves (economic) resources (all potentially economic rock, including currently economic) and "occurrences" (deposits not regarded as potentially economic in the foreseeable future).</p> <p>The reviewers include a figure of the "resource box", which contains "economic deposits", resources as uneconomic deposits which have a reasonable potential of becoming economic at some point and "geopotential" – the deposits presently "unknown" from which future reserves will be sourced, similar to their analysis in Scholz and Wellmer, 2013. In our paper, we made the following observation in respect of this "geocapacity":</p> <p><i>A recurring issue in the literature is that a very substantial geocapacity of undiscovered PR deposits may exist that may extend reserves and resources well beyond currently known reserves and resources (Sheldon, 1987, and, more recently, Scholz and Wellmer, 2012). However, a distinction should be made between known or hypostasized occurrences based on assumed extensions of known deposits, and truly unknown geocapacity². In view of their typically high uranium content, aerial radiometric detection of PR is possible and is routinely applied in the exploration of PR deposits (Asfahani et al., 2005). Van Kauwenbergh (2006, p. 46) argues that, while there may be some potential to discover new deposits, oil exploration programs have probed most of the coastal sedimentary basins</i></p>

² In the paper, a footnote is inserted here which reads: "Hypothetical deposits are undiscovered resources similar to known mineral bodies which may reasonably be expected to exist in the same producing district under analogous geologic conditions, while speculative deposits are resources that may exist under favorable geologic settings, but where no discoveries have yet been made (USGS, 1980)."

		<p><i>of the world during the past 20 to 30 yr, and that any large scale discoveries of phosphate rock probably would have occurred in conjunction with these activities. Smit et al. (2009) refer to a personal communication by USGS that the discovery of major new deposits is unlikely.</i></p> <p>The reviewers do not respond to this, other than that "<i>it is wrong and far too pessimistic to assume that no new discoveries of PR deposits can be made</i>" (review, C2). This is obviously not what we stated. The point is that there appears to be a fairly significant knowledge as to where the largest PR deposits can be found. We noted that this should be kept in mind when considering the concept of "geopotential". The reviewers did not respond to this.</p> <p>In the paper we stated that there are very large known deposits offshore and deep underground, known or reasonably expected to exist, based on exploration. We believe it would be very worthwhile if the knowledge on these deposits would be brought together and made more accessible. This is consistent with the proposal in the IFDC report:</p> <p><i>A Phase II initiative has been envisioned to be similar to the IGCP Project 156 – Phosphorites, but with the objective to explore future world phosphate rock reserves and resources.</i></p>
4	<i>The boundaries are always dynamic. What are resources today can be reserves tomorrow and vice versa. This applies also to the boundary between geopotential and reserves and resources. Due to exploration work or technological development geopotential can become reserves and resources.</i>	All discussed in our paper.
5	<i>With respect to quantifying all reserves and resources, no company or institution has the interest or the means to do so. In general, companies only spend money, at a high risk, on exploration if they can bring the deposits quickly into production.</i>	In chapter 3, when discussing JORC style financial classifications, we described that companies have no incentive to perform the kind of detailed exploration for establishing reserves beyond a reasonable planning horizon. However, this is not to say that companies and governments perform no exploration to locate potentially viable deposits. See our response to comment C1(3) above and comment C1(9) below.
6	<i>Reserves and resources can only be snapshot in a dynamic process of resource evaluation</i>	This is a main tenet of the reviewers. A key assumption relating to it is that we cannot know the ultimate quantity of PR that is available. Given that reserves are usually only a fraction of the total resources available, it is also important to have reliable knowledge of those deposits from which future reserves and resources will be sourced (Cathcart et al., 1984; Van Vuuren et al., 2010). This is what IFDC proposed to investigate, see our response to comment C1(5) above.
7	<i>For companies, reserves are their working inventory. They, therefore, normally only gather data and estimate reserves for as many years of production as the cost associated with obtaining the data and their preference for business planning justify; i.e., the reserves may be more dependent on business planning models and investment alternatives than on the magnitude of minerals in the ground. These reserves normally have to comply with the</i>	The reviewers argue that companies have no incentive to perform the kind of detailed exploration required to establish reserves beyond a reasonable economic planning. We discussed this point when describing JORC style financial classifications. Also discussed above.

	<i>JORC/CIM code for reserve reporting, today one of the international standards.</i>	
8	<i>Looking at government bodies, regional planning authorities often have to plan further ahead. The quantities have to be economically extractable before the planning permits are granted. But the “modifying factors” (like legal, environmental, social, and governmental factors) are not in place yet—the task of such government bodies is to clarify the aspects of the “modifying factors.” For these reasons, a government body would probably speak of reserves, although the JORC/CIM conditions are not fulfilled.</i>	<p>The reviewers argue that a different granulation should be linked to classifications for different stakeholders. The essence of the reviewers' comment is that, under JORC type classifications, reserves have to meet even more stringent requirements than would have been the case under government type classifications as JORC style classifications not only look at economic, technological and mining "modifying factors", but also to social, legal and governmental constraints. We agree that is a valuable contribution and we will incorporate it in the paper.</p> <p>However, we note that this does not influence our findings in relation to the first research question: whether IFDC's proposal to discard granularity in the USGS classification is appropriate. Our finding was that IFDC's proposal to discard granularity was inconsistent with each of the three classifications reviewed (USGS, JORC and UNFC) which each contain detailed thresholds for reserves and resources. The fact that JORC contains even higher thresholds for the demonstrated economic category ("reserves") than USGS does not invalidate this finding.</p> <p>In addition, we note that the UNFC classification aims to be fully compatible with JORC style classifications so that any difference in the standards used should be reflected.</p>
9	<i>Mining and exploration is the task of industry, normally not one of government agencies. Only in exceptional cases will government agencies drill in the forefront of industrial activities.</i>	<p>A recurring statement in the review, the IFDC report as well as Scholz and Wellmer (2013) is that exploration is performed by mining companies who only will perform exploration within a commercial planning horizon. A necessary consequence of this would be that data regarding reserves and resources would simply not be generated beyond the level of what is commercially feasible. In other words, there would be no real exploration beyond what is in the direct interest of the industry.</p> <p>We agree that detailed exploration for reserves is a task of industry and that industry has a limited planning horizon. Chapter 3 of our paper deals addresses this point explicitly. However, it appears that governments and government branches have played an important role in the past in the exploration of deposits which are not immediately regarded as economically viable and sometimes are even not regarded as resources. This is particularly true for the US, as recognized in Scholz and Wellmer, 2013:</p> <p><i>"In the US, there is a long history of exploration and exploitation, in particular around the Western Phosphate Field (WPF) in Idaho, Montana, Utah and Wyoming, The WPF was first explored by the Geological and Geographical Survey of the Territories, 1871-1877 (Jasinski et al, 2004) and four USGS field programs between 1909 and 2002."</i></p> <p>As explained in our response to C1(3) above, it appears that there is considerable knowledge as to major PR deposits and where they are located. To increase our understanding of these deposits, a further research project as envisaged in the IFDC report would be very useful.</p>

10	<p><i>In consequence for long term outlooks government agencies have to draw conclusions from drill hole information and grids which do not yet fulfill industry standards under rules of stock exchanges and financing banks. This applies also to a worldwide balance like the Mineral Commodity Summaries (MCS) of the USGS. Australia is a good example. The USGS uses in the MCS for their Australian reserve figure the Accessible Economic Demonstrated Resources (EDR), which is practically identical with the EDR figures (Australian Government, 2011; Lambert, Mietzitis, Carson, & McKay, 2012) It is also a good example how, in a country which applies strict standards, the EDR figures (meaning the reserve figures in the MCS) can grow from one year to the other and how it relates to JORC reserves of industry. In 2010 the EDR for phosphate rock was 490 Mt, in 2011 it practically doubled to 950 Mt. The share which fulfilled the classification of reserves under the JORC system was only 280 Mt (30% of the EDR)"</i></p>	<p>The comment that government classifications do not necessarily fulfil all requirements under financial classifications has been discussed above.</p> <p>The reviewers state that USGS uses Australian "Economic Demonstrated Resources" (EDR) for its Mineral Commodity Summaries (MCS). This statement is not supported by the sources which the review provides. The reviewers cite a power point presentation by Lambert, Mietzitis, Carson & McKay (2012) and a webpage from the Australian government (Australian Government, (2013). Lambert et al. describe how the Australian government reports EDR which consists of JORC proved and probable reserves as well as JORC measured and indicated resources. However, the presentation does not state that USGS uses the EDR figures for its MSC. They merely state, on a slide discussing foreign government classification systems, that USGS "reserves" reporting is "comparable" with EDR and does not equate with JORC.</p> <p>Furthermore, we note that the reserve data in USGS' MSC do not correspond with the MSC numbers as reflected in the left column. In 2010, USGS 2010 reported reserves of 82 Mt PR for Australia (USGS, 2010), compared to EDR of 490 Mt. In 2011 and 2012, it reported reserves of 250 Mt PR (USGS 2011 and 2012), compared to 280 Mt PR reported in 2011 under JORC (Australian Government, 2013) and a reported EDR of 950 Mt PR. In 2013, USGS reported reserves of 490 Mt PR (USGS, 2013). These figures do not support the statement that USGS uses Australian EDR data for its MSC.</p> <p>The reviewers also use the Australian example to show how the EDR numbers can grow from one year to another. In other publications (Scholz and Wellmer, 2013, p. 5), the reviewers used the increase of Moroccan reserves and reserves of certain other countries (Algeria, Syria, Iraq) to prove the same point. We discussed these increases in our paper (chapters 4.2 and 5), but the reviewers did not (Algeria, Syria) or hardly (Iraq, Morocco) discuss these. Providing yet another example of increasing PR reserves seems to add little to the discussion.</p>
<p>C2 The Hubbert curve and peak phosphorus application to the global data are scientifically unacceptable</p>		
<p>Scholz and Wellmer</p>		<p>Response</p>
1	<p>Citation concern 2: <i>"While there is broad agreement that PR is a finite resource essential for human survival, the longevity of minable PR deposits is the subject of intense debate. Numerous articles have modeled depletion of PR reserves to occur by the end of the 21th century (Steen, 1998; Rosemarin, 2004; Vaccari, 2009), or peak phosphorus to occur within even a few decades from now (Déry and Andersson, 2007; Cordell et al., 2009). (p. 1007)"</i></p> <p>Following this citation, the reviewers state:</p>	<p>Scholz and Wellmer submit that our paper is biased because it refers to the peak phosphorus hypothesis, without taking into account that this hypothesis is disputed in the literature (i.e. Vaccari and Strigul, 2011, Rustad, 2012 and Scholz and Wellmer, 2013). The reason why we identified the peak phosphorus hypothesis was because the IFDC report was issued partly in response to these papers. Peak phosphorus formed no part of the research questions, was not among the keywords submitted with the paper and has already been described extensively in the literature. Moreover, we cited the main papers in which the peak phosphorus hypothesis is rebutted (Vaccari and Strigul, 2011, Scholz and Wellmer, 2013 and Mew, 2011) albeit in another context.</p> <p>We note that we did place the peak P and "this century depletion" hypotheses into context, explaining that these articles were based on USGS reserve data; that reserves are only part of the total resource box, and that resources reported in Notholt et al, 1989 are much larger than USGS' reserves.</p>

	<p><i>The uncritical way in how articles are cited that have modeled an end of peak phosphorus “by the end of the 21st century” (p. 1007) is absolutely unacceptable for a paper which pretends to offer an “in depth-estimate literature review of ... global rock reserves ...” (p. 1009).</i></p>	<p>To address this comment, we will include references to these papers in relation to peak phosphorus as well as this point is well covered in the scientific literature.</p> <p>As to the reviewers' reference to the title: The subtitle is misquoted and reads: <i>“an in-depth literature review of global estimates of phosphate rock reserves and resources.”</i> The title itself, not cited, reads: <i>“recent revisions of phosphate rock reserves and resources: reassuring or misleading”</i>. It is clear from this title, the subtitle and the research questions that the paper deals with the recent update of global estimates, not with resource theories such as peak P.</p>
2	<p><i>There is no reason to assume that the USGS recording is complete. It just records the state of knowledge at the time of publication.</i></p> <p><i>We know from many other minerals that the reserves can increase (reserve growth), in particular if there has been pressure to launch comprehensive exploration for industry (which has been the case for oil, far more than for phosphate rock so far)</i></p>	<p>We discussed in numerous places in the paper that USGS' reserves which by no means represented the whole quantity of potentially extractable PR on earth. We referenced resources to be 163 000 in Notholt et al (1989) and nearly double that in the IFDC report. We discussed these resource figures to the extent they relate to Morocco. We discussed that beyond resources, there are large occurrences, including large offshore deposits.</p> <p>No doubt other deposits will become available for mining and will become resource of even reserves; we acknowledged that a number of times in the paper.</p>
3	<p><i>Edixhoven et al. cite for the support of the ‘this century depletion’ statement the 2009 contribution in Scientific American magazine in which Vaccari predicts a depletion in 90 years based on a static lifetime prediction (i.e., dividing the documented resources by the current annual consumption of that time) using a reference of 15 Gt reserves (Vaccari, 2009). However, they do not even mention the later paper which Vaccari co-authored with the mathematician Strigul in the high ranking journal Chemosphere which already includes in the abstract the key message: The “Hubbert-type extrapolations are not robust for predicting the ultimately recoverable reserves or year of peak production of phosphate rock.” (Vaccari & Strigul, 2011).</i></p>	<p>Again, we did not support Vaccari's "one century depletion" statement but merely identified it to show there is a discussion. See our comments to C1(1)</p> <p>Other than the reviewers state, we did cite Vaccari and Strigul (2011), albeit in the context of a failure to distinguish between ore and concentrate. See section 4.3 of our paper. The reviewers did not respond to this.</p>
4	<p><i>One may question why this severe neglect and biased review is presented in the beginning of the “Problem statement” (p. 1007).</i></p>	<p>The "severe neglect" and "bias" argument is somewhat overstated in our view. Reference is made to our response to the comments above.</p>
<p>C3 Improperly interpreting and using the concept of lifetime (the R/C ratio)</p>		
<p><u>Scholz and Wellmer</u></p>		<p><u>Response</u></p>
1	<p>Citation concern 3: <i>“In view of the above, depletion of currently identified easily accessible deposits could occur at much quicker rates than suggested by the IFDC report, depending on how society responds</i></p>	<p>As stated above, in our paper, we explicitly recognized and worked from the notion that reserves and resources are dynamic. In their criticism in the left hand column, the reviewers again suggest that we did not.</p> <p>The paragraph on which the reviewers base their criticism is quoted partially. Quoted in its entirety, the paragraph</p>

	<p><i>to potential risks of long term PR scarcity (p. 1013)”. The reviewers conclude from the above citation: "The authors seem to misunderstand the character of the R/C ratio (reserve to consumption or reserves to production ratio, the differences of which over the long run are only influenced by the amount of stockpiling). This ratio is not the life time of a commodity. Also when discussing the Western Phosphate Fields (WPF) in the US, Scholz and Wellmer (2013) stressed the limitations of this R/C ratio. A large body of literature exists outlining the arguments for example from J. Zwartendyk, formerly with the Wenergy, Mines and Resources Canada, who called the life index a statistical mirage (see Zwartendyk 1974 or Wellmer 2008). We also wonder why it never occurred to the authors that the USGS in its Mineral Commodity Summaries and Minerals Yearbook publication does not never publish a lifetime or an R/C ratio (Jasinski, 2012; USGS, 2013).</i></p>	<p>reads: " <i>In view of the above, depletion of currently identified easily accessible deposits could occur at much quicker rates than suggested by the IFDC report, depending on how society responds to potential risks of long term PR scarcity (p. 1013). It is therefore of great importance to have reliable knowledge regarding the quantity of PR that is available for potential extraction. This brings us to the first research question, whether, as IFDC advocates, a resource classification with little granulation is indeed desirable for the purpose of creating a reliable long term global inventory of PR.</i>"</p> <p>This paragraph was preceded by a discussion of possible future PR consumption rates in a number of scientific papers, including a scenario analysis by VanVuuren et al (2010) on the basis of the four scenario's in the UN Millennium Assessment, a number of which indicated significantly higher future consumption rates than the static rate adopted in the IFDC report (Van Kauwenbergh, 2010a).</p> <p>It is evident from this fragment that we were not referring to the R/C ratio here, but were making the point that any modelling of PR depletion requires reliable data on not only reserves and resources, but also those deposits which are not currently considered a resource or reserve, but may become so in the future.</p>
2	<p><i>Firstly, the units of reserves shall be explained. Companies have to report the reserves with tonnage and grades (see e.g. Joint Ore Reserve Committee JORC, undated). For global reporting it is standard to report reserves as marketable product. This is understood by geoscientists and engineer in the mineral resources field.</i></p>	<p>Our second research question (discussed in chapter 4 of our paper) reviews whether the difference between ore and concentrate is sufficiently understood in the literature. The reviewers do not discuss this research question, but for two isolated and unsubstantiated statements. The first is reflected in the left hand column. The second is contained in comment C3 (7), and holds that it would be "irrelevant" to consider losses at the beneficiation plant because only "orders of magnitude" would matter. Reference is made to our response to that comment. Here, we only discuss the statement in the left hand column.</p> <p>In our paper, we pointed out that the USGS classification contains no indications that reserves should be reported as concentrate; that the JORC classification expresses a preference for reporting as ore reserves and that any report reporting in concentrate should explicitly state so, and that the UNFC classification likewise reports economic deposits in terms of ore. We also provided the necessary sources for these statements. It is not clear from the reviewers' comment in the left hand column whether they agree with our statements in respect of the JORC and UNFC classifications.</p> <p>The statement that "<i>for global reporting it is standard to report reserves as marketable product</i>" is not accompanied by a reference, nor is the statement that this would be "<i>understood by geoscientists and engineer in the mineral resources field</i>". Again, the reviewers discuss our analysis.</p> <p>We note that there are no specific guidelines for "global reporting". The only organization which reports PR reserves globally on an annual basis is USGS. Section 4.2 of our paper deals with the question whether USGS reports in terms of ore or concentrate. We reached the conclusion this was probably ore in a number of instances. In this context, we</p>

		<p>pointed out that the IFDC report, which reports in concentrate, went at great length to recalculate reserve assessments to concentrate, which presumably is why it arrived at substantially lower reserve estimates for a number of countries. See for instance the South African example which mines igneous ore which has a lower P₂O₅ grade but can be upgraded to high grade concentrate. The reserves listed by USGS are 1 500 Mt PR, roughly consistent with the ore number provided by the South African producer, while the IFDC report calculated reserves as 230 Mt PR. The reviewers did not respond to this analysis, nor do they discuss the analysis provided in relation of other countries, such as Iraq.</p>
3	<p><i>Secondly, it is wrong and far too pessimistic to assume that no new discoveries of PR deposits can be made and, therefore, the calculation of an R/C ratio is justified.</i></p>	<p>Reference is made to our response to "Concern 1", sub 3.</p> <p>We nowhere stated in the paper that no new discoveries can be made. We did include a few citations to papers (including Van Kauwenbergh, 2006) which state that the potential for finding truly unknown deposits is limited as most of the world's coastal sedimentary basins have been probed by now, also in the context of oil exploration and major deposits should have been discovered in conjunction with these activities. This section is quoted in its entirety in our response to "Concern 1", sub 3 above. The reviewers do not discuss this.</p> <p>As discussed above as well as in our paper, there are very significant known occurrences which are currently not regarded as resources, such as the Western Phosphate Field and various offshore deposits. The consequence, it seems, is that there is room for further knowledge generation on these deposits which could reduce dependence on concepts such as the R/C ratio.</p>
4	<p>The reviewers discuss large exploration budgets by firms and then ask: <i>"Why would companies spend money if discoveries and even increase their expenditures if discoveries are unlikely?"</i></p>	<p>We recognized there are very large occurrences, even though knowledgeable authors indicate that the potential for finding large, truly unknown deposits is rather limited (see above). This obviously does not impact the rationale for further exploration on PR reserves by mining corporations.</p>
5	<p><i>In addition the effect of reserve growth has to be considered. In sedimentary deposits like phosphate but also salt or coal the major replacement of mined inventory (reserves) occurs by so-called reserve growth.</i></p>	<p>The reviewers use the term reserve growth to describe the phenomenon that "reserves" on a global scale increase due to further exploration. However, Reserves – if established correctly – are only a fraction of the resources (Van Kauwenbergh (2010a p. 18).</p> <p>Unless humanity will be mining PR from ordinary rock, (Wells, 1975) humanity will depend on PR deposits forever. In view of the finiteness of PR deposits, the focus on reserves and reserve growth may not be appropriate for PR. This is why we stressed, consistent with the IFDC report, that more research is required to estimate the deposits from which reserves and resources will be sourced in the future.</p>
6	<p><i>Scholz and Wellmer (2013) explained that the R/C ratio can be a useful early warning indicator</i></p>	<p>For the same reasons stated in our response to the comment above, adopting an intergenerational perspective, the R/C ratio seems ill suited as an "early warning indicator". If the R/C ratio is used for this purpose, this stresses the need for reliable data on PR reserves.</p>

7	<p><i>Therefore, and because the ratio is not the life time, it is irrelevant to consider losses in the mining operation and in the beneficiation plant (Edixhoven et al. 2013, p. 1022, line 26). Only orders of magnitude matter.</i></p> <p><i>The relevant question is to understand the meaning of the absolute R/C ratio and the dynamics of reserve development.</i></p>	<p>This statement contains the second unsubstantiated comment in view of research question 2: is the difference between ore and concentrate sufficiently understood? Their first comment was that it is "understood" that global reporting is in concentrate, see C3(2) above. The second is that this difference is "irrelevant" because "only orders of magnitude matter".</p> <p>We find this statement incomprehensible, as a lack of clarity in this respect seriously impairs transparency and comparability of reserve data. The relevance of the difference between ore and concentrate is stressed by the fact that the IFDC report reduced the high grade Moroccan reserves by 63% to arrive at concentrate, assuming mining losses of only 5%. As discussed in section 4.2 of our paper, it is currently uncertain whether reserves for many countries are reported in terms of ore or concentrate.</p> <p>The comment that "only orders of magnitude matter" appears to relate to our discussion of the Western Phosphate Field in the paper. We criticized Scholz and Wellmer, 2013 for failing to consider losses in mining and beneficiation for deposits which, according to Bauer and Dunning, 1979, are located at depths extending to 9 km and which – because of their depths –were not considered a resource in the context of Project 156 (Sheldon, 1989, see section 4.3 of our paper). There currently appears to be insufficient knowledge on global PR deposits beyond current resources to warrant such a statement.</p>
8	<p>The reviewers ask:</p> <p>(a) is the R/C ratio decreasing? (potential early warning indicator)</p> <p>(b) is it stable within a corridor? Normal situation</p> <p>(c) <i>"Is the ratio increasing, i.e. the learning about reserves and resources is ahead of consumption? This is the case for PR. So mankind is on the safe side. The question of course is how long this will last. No doubt the share of secondary phosphorus has to increase. Research has to be intensified with the aim that secondary phosphate can increasingly be competitive with primary phosphate and take over an increasing market share. This can be observed with other commodities e.g. aluminum (Wellmer, 2008).</i></p>	<p>In our paper, we did not discuss the R/C ratio. In view of the dynamics of reserves, we do not think the reserves/consumption ratio is a reliable indicator from an intergenerational perspective. If the concept is to be used in such manner, one should have certainty that reserve data are reliable and transparent.</p> <p>The reviewers question "how long this [reserve growth] will last". To have any visibility on this question, one should have more clarity as to the deposits from which future reserves and resources will be established.</p> <p>We fully agree that further analysis on the possibilities of recycling PR is desirable. This, however, is clearly beyond the scope of this paper.</p>
C4 Understanding classifications and numbers from a functional perspective		
<u>Scholz and Wellmer</u>		<u>Response</u>
Granularity		
1	<p>(A) <i>Firstly it has to be stated that in all national and international classification systems to be able to classify ore reserves for company statements a "competent person" is required. The definition, similar in all classification systems, is: "A Competent Person must have a minimum of five years' experience working with the style of mineralization and type of deposit under consideration</i></p>	<p>Concern 4 relates to issues discussed in view of the first research question: is IFDC's proposal to discard granulation in agreement with classification principles applied in leading classifications and are the simplified definitions likely to yield comparable and transparent data? In sub (A) of "Concern 4", the reviewers argue that IFDC and USGS analysts should be viewed as "Competent Persons" or "CP's". The reviewers refer to the definition of a CP in the JORC classification which aims to secure that reliable data is provided to investors and the financial markets. We have the following observations to this statement.</p>

<p><i>and relevant to the activity which that person is undertaking” (JORC undated). The equivalent is true for global reporting. There can be no doubt that the USGS mineral commodity specialists responsible for their chapters in Mineral Commodity Summaries and in the Minerals Yearbook as well as the IFDC experts have seen many deposits of phosphate rock and other mineral commodities worldwide and are very experienced long-term ore deposit experts who can draw many comparisons between deposits under exploitation and ones still not exploited</i></p>	<p>Article 4 of the JORC code sets forth that it is based on three principles: transparency, materiality and competence. Transparency requires that the reader of a report is <i>“provided with sufficient information, the presentation of which is clear and unambiguous, to understand the report and not be misled by this information or by omission of material information that is known to the Competent Person”</i>. Materiality entails that the report contains all relevant information which the users would reasonably require. Competence requires that the report be <i>“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)”</i>. 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:</p> <p><i>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</i></p> <p>The definition of a Competent Person as provided by the reviewers is incomplete as it does not include the elements aimed at providing safeguards for maintaining transparency and materiality.</p> <p>Also, we note that there is no standard for a CP for global reporting. The USGS classification does not use the concept. The initial, 1997 version of the UNFC used a simplified definition of the CP which is comparable to the one proffered by the reviewers. This definition was criticized for being <i>“too vague to be of any practical significance”</i>, particularly because no mention was made of <i>“any accountability or membership to a professional body with an enforceable code of conduct”</i> Camisani Calzonari (1997). The current version of the UNFC no longer contains reference to the concept of a CP.</p> <p>While we agree that introducing a CP concept for global reporting could be very 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.</p> <p>Whether USGS analysts could qualify as CP's in the context of the JORC classification is beyond the scope of this paper. We note the USGS classification does not use the concept of a CP.</p> <p>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 mean that his findings could not be subjected to criticism. The statement that IFDC experts should be regarded as CP's has little bearing on our analysis</p>
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		regarding Moroccan reserves and resources, as discussed in our response to Section C 4 (10) below.
2	(B) <i>"The second reviewer is very knowledgeable when it comes to mining; he has seen a lot of instances where resources have been transferred to reserves."</i>	Again, we recognize these dynamics throughout our paper.
3	<i>No clear cut exactly defined boundaries between reserve/resources categories exist. Two different competent persons do not necessarily come to the same conclusion. Reserve/resource classification is not an exact science.</i>	<p>Each of the classification systems we reviewed attempts to set boundaries for various classes of resources and reserves using specific requirements. This is discussed in chapter 3 of our paper and also applies to the UNFC.</p> <p>A recurring element in the literature is that the really large differences are nearly always the result of incorrect or inconsistent terminology used (Cathcart et al., 1984). It is for that specific reason that the USGS, JORC and many other classifications were created. The UNFC aims to achieve further consistency in reporting of resources. It is increasingly accepted that it is useful to <i>"map the various classification and reporting systems for mineral and energy resources to a common base"</i>, to <i>"check harmony between the systems"</i> and <i>"enable valid comparisons between countries' inventories and better estimates of world stocks"</i> (Lambert et al (2012)).</p> <p>While there will always be room for errors, clear requirements for resource categories will increase comparability and transparency. It is for this reason that we critically viewed IFDC's proposals to discard granulation.</p>
4	<p>Subheader: "Granularity"</p> <p><i>How difficult it can be to fit a specific country system into the new UNFC shows very well the Russian example as outline by Gert (2007). The proper transferal of Russian categories was also the reason for the changes in the MCS of the Iraqi figures in the USGS reporting from 2012 to 2013</i></p>	<p>This comment refers USGS' restatement of Iraq reserves in 2012 from zero to 5 800 Mt PR ore, and the subsequent reduction to 430 Mt PR ore in 2013 (see: discussion in C1 (7) and section 4.2 of our paper). The reviewers state that it would be difficult to transfer Russian resource categories to the UNFC system, referencing a power point presentation with visuals but no explanatory text (Gert, 2007). The reviewers then state that the proper transferral of Russian these categories was the cause for the downgrading of the Iraq reserves in USGS' MSC, but do not provide a source for this statement. We note that the former Soviet Union had a reputation for detailed reporting on resource classes and that the UNFC system was designed to conform to this³.</p> <p>As we noted in the paper, the main PR deposits which USGS described in detail in Taib (2010) had already been described decennia earlier in the context of the Unesco/ IGCP Project 156 (Al-Bassam, 1989). For instance, the Swab deposit, described in Taib, 2010 as 3,503 of rock grading 22% P₂O₅, was already described as a resource of 3 500 grading 22% P₂O₅ in Al-Bassam, 1989. Likewise, the 430 PR minable reserve, grading 22% P₂O₅ which is currently entered in USGS' MSC was already described as a reserve (Al-Bassam, 1989) p. 322. Apparently, the majority of the large resources did not meet the standards for reserves and apparently, this is no different today. Again, granulation in a classification with clear thresholds appears helpful to ensure that deposits are not classified in an incorrect resource</p>

³ See: Camisani Calzolari (2006): *"The main motivation behind the compilation of such a code [the UNFC] was the liberalization of the former Eastern Bloc at the fall of communism in Russia in 1990. As a consequence, Russia and its former allies realized that in order to attract international capital to develop their mineral resources they needed to report their mineral potential in a way that was understood by the Western world, particularly by the market and the financial institutions. At the same time the immense wealth of detailed information stored in their large databases, which was the result of years of painstaking collating of data by a large workforce, had to be kept and updated without major disruptions or changes. This had to be done for two reasons, firstly this information represents an invaluable asset to the state and secondly the whole reporting system consists of a rigid but well organized structural framework which is deeply rooted in the mining tradition of these countries. The UN-ECE was chosen as the vehicle to develop such a classification.*

		category, and are comparable.
5	<i>When the UNFC was invented the granularity followed accepted practices and tried to reach as much consensus as possible. It is up to each country, however, to decide what categories it reports.</i>	What matters is that there is a movement towards a more uniform use of data, both for government reporting and for financial markets reporting and that this development, embodied in JORC and the UNFC, is aimed at creating increased transparency and comparability through the use of recognized thresholds for mineral resource classes (granularity).
6	<i>The authors deplore the suggestions by the IFDC to simplify the granularity of the USGS system, to discard the category “reserve base” (van Kauwenbergh 2010) and only use the categories “reserves” and “resources”. The authors do not seem to be aware why the USGS stopped using the category reserve base already in 2010 for reasons outlined below.</i>	<p>We reviewed the suggestions to discard the granulation contained in the USGS system and replace it with two definitions which contain no further granulation: 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.</p> <p>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 such simplified terminology 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. While the reviewers comment on numerous aspects of resource classification and include some useful additions for our analysis, this research question and our related research findings are not discussed.</p> <p>Instead, the reviewers focus entirely on a sidestep in our paper, namely the proposal to discard the reserve base. The only thing we stated about the reserve base is that the argument to discard it (clear monetary thresholds are required, which require continuous updating) applies <i>a fortiori</i> to reserves as these require even more detailed thresholds.</p> <p>The reviewers comment that USGS discontinued the practice of reporting a reserve base in 2010 because the US government had already discontinued funding for establishing this resource category already in the mid-nineties. This is informative but has little relevance to the paper. To clarify the discussion further, we will remove our comments in respect of the reserve base.</p>
7	<p><i>The question has to be asked, however, how desirable it really is to spend means on obtaining a high granularity for reserves and resources with an R/C ratio larger than 100.</i></p> <p><i>The boundaries can only be defined with economic and technical criteria derived from the present state of technology. Looking at other commodities with a more transparent data base like for example copper: Who would have dared to predict 100 years ago,</i></p>	<p>The reviewers subscribe to the notion that data on PR reserves and resources must be reliable and comparable. As noted above, the reason why granularity in resource classification is desirable is that this enables valid comparisons between countries' inventories and enables better estimates of world stocks (see also: Lambert et al. (2012)).</p> <p>The reviewers question whether it is desirable to expend the costs for maintaining granularity when the R/C ratio is larger than 100. Our reservations with respect of the use of an R/C ratio have been discussed above.</p> <p>As for the costs issue we note the following. Elsewhere in their paper, the reviewers appear to argue that transferral of</p>

	<p><i>when the average grade of copper mined was above 1%, that 100 years later copper ore was profitably mined with grades below 0.4%? This occurred with constant prices in real terms in the long run (Scholz and Wellmer 2013, Chapter 4.2 and Fig. 14)</i></p>	<p>national data to the UNFC system is simple. Indeed, the only thing required under the UNFC is that every deposit needs to be accurately placed in a category, reflecting the extent to which the deposit is known and reflecting its economic potential (UNFC, 2010). Similar principles are incorporated in the USGS classification. Entering deposits in a universal template such as the UNFC does not primarily appear to be a major cost issue. As discussed above, the desirability of maintaining granularity appears to be widely accepted in the literature and forms the basis of each of the classification systems we reviewed.</p> <p>The reviewers argue that changing technological criteria should be continuously incorporated in the boundaries between the various resource classes. We agree. It should be noted, though, that technical developments have been rather limited in the context of PR over the last decennia (Van Kauwenbergh, 2010a).</p>
8	<p><i>It would be much more worthwhile to establish learning curves as tools to extrapolate into the future about grade developments, increase in the efficiency of beneficiation, increase in mining efficiencies to mine seams with higher waste: ore ratios etc.</i></p>	<p>Again, the reviewers appear to argue that we should have written another paper. These comments are beyond the scope of our research questions.</p>
9	<p>Subheader: Company data transfer to one world number;</p> <p>If done within the UNFC system transferal of national data to the USGS system used in the MCS is simple. An excellent example may be the Australian data as outlined above. The Australian government authority Geoscience Australia determines EDR Economic Demonstrated Resources (Lambert et al. 2012). The USGS uses accessible EDR for the Australian reserve figures in the MCS, which is practically identical with the EDR figures (Australian Mines Atlas 2011). It is also a good example <i>how</i> in a country which applies strict standards the EDR figures (meaning the reserve figures in the MCS) can grow from one year to the next one. In 2010, EDR was 490 Mt, in 2011 it practically doubled to 950 Mt. The share which fulfilled the classification of reserves under the JORC system was only 280 Mt (30% of the EDR).</p>	<p>This is a nearly exact repetition of what the reviewers' statement reflected in C1(10) above.</p> <p>As discussed there, the sources given by the reviewers provide no support for these statements. In fact, the numbers in the USGS' MSC appear to be more close to the JORC reserves.</p>

10	<p>Subheader: Transfer of drill hole distances from one country to another"</p> <p><i>The authors criticize the Moroccan reserve numbers of the IFDC and the MCS. They compare distances of drill holes for reserve determination of the US with the ones in Morocco. Although the Moroccan and the US deposits are of the same sedimentary type there are differences from region to region. The authors neglect such possibilities. This is also the reason that "competent persons" are required as described above to judge which rules can be transferred and which one have to be modified for what reasons. It is not appropriate from a geostatistic view to apply the same sampling (drilling) plan for different sites to assess reserve</i></p> <p><i>For comparison we shall use another commodity which also occurs in seams normally continuing over large distances similar to phosphate seams and for which more data are available: coal. The Australian regulations for coal accept for the highest category of measured inventory coal and measured coal resources a drilling grid up to 500 m, "but the distance may be extended if there is sufficient technical justification to do so (Coalfields Geology Council of NSW and Queensland Mining Council, 2003). The Canadian regulations accept for the same categories for a certain coal type 800 m (Hughes, Klatzel-Mudry, & Nikols, 1989). The same is true for the Ukraine (Schmidt, 2007) – all three very experienced coal mining countries. For the category "indicated" the distances are in Australia 1000 m (which as before may be extended), in Canada up to 1600 m, in the Ukraine up to 4000 m.</i></p> <p><i>This underlines the necessity to have (geological) competent persons for reserve/resource classification and also persons with specific commodity and country knowledge, conditions which are fulfilled in the USGS and the IFDC.</i></p>	<p>The third research question in our paper is whether the estimate of PR reserves and resources contained in the IFDC report is reliable, focusing on IFDC's restatement of Moroccan reserves. As set forth in the paper, the Moroccan findings in the IDFC report were based on a single paper (Gharbi, 1998). Here, our method was to trace back the data sources used in the IFDC report and analyze whether they were consistent with the findings in the general literature. We provided a detailed and thoroughly referenced analysis of Moroccan data on reserves and resources. This analysis revealed, inter alia, that the difference between reserves and resources is often not properly recognized in the literature describing Moroccan PR deposits. This is an issue more often identified in the literature. See for instance Notholt et al (1989) p. xxiv. See also Van Kauwenberg (2004):</p> <p><i>"Many authors do not distinguish between reserves and non-economic resources when reporting the size of deposits. Thus, substantial differences in reserve and/or resource estimates may exist between various sources. It is prudent to acknowledge that such discrepancies exist and that such figures should serve only as order-of-magnitude estimates."</i></p> <p>In our paper, we also showed that the terms reserves and resources had been used very inconsistently in the literature describing Moroccan deposits (paper, section 5.2/5.3). In our paper, we concluded that the Gharbi (1998) estimate, the sole publication on which the IFDC estimate for Morocco is based, apparently likewise uses the word "reserves" where the term "resource" would have been appropriate. We based these findings on, <i>inter alia</i>:</p> <p>(i) numerous OCP annual accounts from around the same period which report the same deposits described in the IFDC report as resources, as well as the 2007 OCP annual account which list a far smaller quantity of ore as reserves (20,000 Mt, consistent with USGS' reserve base in its 2006 MSC);</p> <p>(ii) a paper by Gharbi and Mchichi (1996) which contains more detail than Gharbi (1998) and which integrally reports the same deposits as resources;</p> <p>(iii) an extensive analysis in Van Kauwenbergh (2006) of Moroccan PR deposits in which the author of the IFDC report discussed both the Gharbi (1998) estimate and the USGS (2006) MSC reserve estimates. In this publication, Van Kauwenbergh reached the conclusion that the numbers provided in Gharbi (1998) were probably resources. In this publication, Van Kauwenbergh referred to the USGS (2006) MSC reserve numbers as reserves.</p> <p>Moreover, we noted that reserves generally account for only a small part of the resources in a given production area. The fact that <i>all</i> deposits in three of the four production areas were stated as ore "reserves" is an anomaly. We feel that these elements provide sufficient indications that the interpretation of Gharbi (1998) is not in agreement with the principles of resource classification used in each of the classifications we reviewed. In our view, the report should have explained why IFDC's previous findings in relation to the Gharbi estimate were no longer valid. We note that the reviewers have not discussed any aspect of the abovementioned analysis.</p> <p>In addition to the above, we compared data regarding the quantity of drill holes contained in the OCP annual accounts and Gharbi and Mchichi (1996) to verify if these are in agreement with the drill hole requirements in the USGS</p>
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		<p>classification for US ore fields. This is the only element which the reviewers do discuss. Scholz and Wellmer dispute our findings here, stating that it is not certain whether requirements designed for US ore fields can be transferred to the Moroccan context. We agree that this is a useful comment and that the uncertainty regarding appropriate Moroccan borehole requirements should be incorporated in the paper. We will address this in the final version of the paper and reflect this uncertainty in our conclusions as well. However, we also note that the reviewers provide no data which proves our analysis wrong.</p> <p>The reviewers reference differences in grid requirements for coal for a number of countries but provide no borehole requirements for PR for Morocco. In the paper, we referenced Van Kauwenbergh, 2010a, who stated that "in most places of the world, to establish "proven" reserves, boreholes and samples are drilled at approximately 100-m centers". According to the OCP annual account over the year 2000, more than half of the aggregate Moroccan "resources" were established at boreholes spaced more than 2000 meters apart (OCP, 2000). We also indicated that, in addition to requirements related to measurement, economic requirements apply which were not considered. This also contributed to our analysis that the use of the term "reserves" is probably not appropriate for these deposits. The facts that these deposits were qualified as resources in OCP (2000) ("toutes qualités confonfues", or "all qualities aggregated") and the fact that OCP (2007) used a much lower number for reserves (20,000 Mt PR, consistent with USGS' reserve base at the time), support our findings. The gridhole data also appears consistent with Savage (1987) who indicates that "<i>only around the established mining centres are reserves accurately and proven</i>". Finally, we note that the deposits under scrutiny are qualified as resources in each of the documents in which the gridhole data was provided (OCP 1987, 1995, and 2000 and Gharbi and Mchichi, 1996).</p> <p>The third comment in the left hand column – that IFDC/USGS should be recognized as "competent persons" – is discussed in C4(1) above.</p>
C5 Transdisciplinary processes such as the Global TraPS project should be presented in a correct, well-referenced, unbiased and fair manner		
	<u>Scholz and Wellmer</u>	<u>Response</u>
1	<p>Citation concern 5:</p> <p><i>Following its report, IFDC created a network, Global TraPS (http://www.globaltraps.ch). This network focuses on the supply side of phosphorus and aims to bring together members from practice ien academia in order to foster knowledge to deal with the problem of phosphorus. The project is co-led by the CEO of IFDC as a "practice" representative, while Dr. R. Scholz of the Swiss Technology Institute represents academia. Along with industry, the network attracted numerous scientists and organizations as members. (p. 1008-1009)</i></p>	<p>The reviewers state that, factually, the foundation Global TraPs has nothing to do with the IFDC report. We agree.</p> <p>Scholz and Wellmer also indicate that we inadvertently stated that IFDC created the Global TraPs project while it was in fact initiated by Mr. Scholz, representing science. This is also correct. While the project incepted after IFDC, represented by its CEO, Mr. Roy, become the project's CEO representing practice (Global TraPs (2011)), the reviewers correctly point out that the project was initiated by Mr. Scholz. We will correct this in the paper.</p>

	<p>The reviewers then state:</p> <p><i>This statement well represents the sloppiness of this “in-depth review.” But, it also may include some phrasings which are close to miscrediting IFDC and the Global TraPs project. Factually, the foundation of Global TraPs has nothing to do with the IFDC report (the first reviewer and initiator of the Global TraPs project even did not know IFDC nor the Van Kauwenbergh (2010) report when he initiated Global TraPs). Also the statement that Global TraPs focuses on the supply side is incorrect.</i></p> <p><i>Let us briefly document the superficial and biased review:</i></p> <p><i>(i) It is wrong that “IFDC created the network” (p. 1008) Global TraPs has been initiated first by science. This is well represented in a paper published in Science of the Total Environment: “The Global TraPs project was initiated by science (Scholz, Ulrich) in 2010 and the overall project started under the joint leadership of Dr. Amit Roy (IFDC) and Prof. Roland Scholz (ETH Zurich) on February 6, 2011. ... (Scholz, Ulrich, Eilittä, & Roy, 2013, p. 801-802)</i></p>	
2	<p><i>(ii) It is a wrong presentation that Global TraPs “focuses on the supply side of phosphorus.” (p. 1008). The guiding question of the Global TraPs project (see Newsletter 5, November 2011) reads: Global TraPs guiding question:</i></p> <p><i>“What new knowledge, technologies and policy options are needed to ensure that future phosphorus use is sustainable, improves food security and environmental quality and provides benefits for the poor?”</i></p>	<p>According to its newsletters, the project initially was supply chain oriented, as reflected in its name:</p> <p><i>Global transdisciplinary processes preparing for sustainably coping with phosphorus from a supply chain perspective.”</i></p> <p>However, we understand that the scope of the project was broadened and, while the name remained the same, the sub header was changed in:</p> <p><i>“Global Transdisciplinary processes for sustainable phosphorus management.”</i></p> <p>We will edit the paper to reflect this.</p>
(C6) Biofuel may most likely have lower impact on P consumption due to already practiced recycling		
Scholz and Wellmer		Response
1	<p>Citation concern 6:</p> <p><i>For instance, Rosemarin et al. (2011) calculated that IFDC’s 60</i></p>	<p>The IFDC report contains the statement that, “[b]ased on this estimate, at current rates of production, phosphate rock reserves to produce fertilizer will be available for 300-400 years.” The current production rate in the report was set at approximately 160 Mt PR concentrate per annum. In the background section of our paper, we discussed that potential</p>

<p><i>000 MtPR concentrate could be depleted within 172 yr if the anticipated population growth is taken into consideration (255MtPR consumption by 2100), or 2100), or 126 yr if Africa would develop its agriculture and experience a green revolution. Under this assumption, global PR concentrate consumption would be 314 MtPR concentrate by 2100, double the quantity on which IFDC based its depletion analysis of current reserves. The authors also calculated that if bio fuels were to supply for 10% of global energy requirement, the reserves reported by IFDC could be depleted in 48 yr, at which point global PR consumption would reach 475 Mt PR annually. (p. 1012)</i></p> <p>The reviewers then continue:</p> <p><i>Again the reference to Rosemarin's calculation (published in a non-refereed source), about the impact of biofuel (instead of 172 yr, a depletion in 48 yr) shows that the authors are not informed about the material flows and existing recycling loops in biofuel production. A large share of the global biofuel production comes from (Brazilian) cane production and (U.S.) maize production. But, there is a very strong recycling loop with respect to P as distiller grains and oilseed meals replace grain in livestock feed.</i></p> <p><i>However, the main concern is with land use and food prices. Compared to this, the impact on P is low. The calculation of Rosemarin et al. (2011) seems questionable as it obviously does not include the dried distillers grains with solubles (DDGS) for ethanol productions. Similarly the (re-use of the biodiesel oilcake is not considered.</i></p> <p>The reviewers argue that "a systemic view is needed the multiple tradeoffs of resource management should have been considered". Also, the reviewers refer to a paper by themselves which is currently in press:</p> <p><i>The biofuel feedstocks are expected to increase. According to a 2011 IFA estimate, biofuel feedstocks received 0.21 Mt P yr-1 (Heffer, 2013). This makes around 3.0% of world phosphorus fertilizer applications. We should note that but most of the</i></p>	<p>future consumption rates are expected to be significantly higher by many analysts. In the context of this discussion, we pointed at Rosemarin et al, 2011 who point out that increased recycling of P is needed in view of potential future use rises if humanity fails to take the proper steps. We also pointed at a scenario analysis by Van Vuuren et al. 2010, conducted on the basis of the four scenario's derived from the Millennium Assessment scenario's (Technogarden, Adapting Mosaic, Order by Strength and Global Orchestration). In the environmentally reactive scenario's, most notably the GO scenario, the consumption rates were also very high, in part because of bio fuels. The point we made on the basis of these papers is that, in an environmentally reactive scenario, PR use could be much higher than the static IFDC estimate, so that reliable data on PR deposits is required.</p> <p>The impact of biofuels was mentioned as part of the background section and forms no part of the research questions. In our paper, we stated that the future role of biofuels could be an important future driver for increased P consumption and suggested this as an area for further research. It would have been beyond the scope of the paper to discuss this background issue more deeply.</p> <p>The reviewers criticize the Rosemarin et al., 2011 paper for not considering recycling of biofuel byproducts. The Rosemarin paper states: "Assuming that one hectare of bio-energy crop produces 90 GJ of net-energy and contains 30kg P, around 135 Mt additional rock would have to be extracted each year if 10% of the global energy demand were to be covered through these crops, <u>unless the P in the resulting ashes and press-cakes were to be fully recycled</u> (Schröder and Bos, 2008)". We will add that the potential for recycling was not incorporated.</p> <p>We have not attempted to verify the extent to which recycling currently takes place and what the net effect of such recycling would be on the P footprint of current and future biofuel production. We have not yet been able to obtain a copy of their paper in press. We will include the potential for recycling in our suggestion for further research.</p>
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	<i>phosphorus found in the feedstocks ended up in oilcakes and slurry which is recycled and thus not lost. Thus, the net impact (after deduction of the phosphorus ending up in co-products) would be much smaller, below 1% (Heffer, 2013).” (Scholz, Roy, & Hellums, in press)</i>	
	C7 Properly understand dynamics of multiple dynamic processes	
	Scholz and Wellmer	Response
1	<p>Citation "Concern 7":</p> <p><i>Scholz and Wellmer argue that one “can define a sustainable P cycle if – in the long run – the economically mineable (primary and secondary) reserves of P increase higher than the losses (i.e. dissipation) to sinks which are not economically mineable” (Scholz and Wellmer, 2012, p. 14). This notion of sustainability, however, requires infinite “reserve growth” which cannot continue forever if the source from which the reserves are derived is finite</i></p> <p>The reviewers then argue that one may mathematically model the way the increase of recycling and access of phosphorus from other sources can to be related to the decrease of accessible phosphorus. The reviewers state that "with phosphorus, we are not facing the situation in which we are fixed pie on a dessert table which is unretrievably disappearing."</p>	<p>This reference to reserve growth was a sidestep in the problem statement. We made this statement to make the point that, ultimately, information is needed in respect of PR deposits. Again, this is consistent with the IFDC report and the reviewers agree this should be an issue of further research (see below).</p> <p>URR refers to Ultimate Recoverable Resources. The reviewers essentially appear to say that when rock PR becomes less economically viable for mining, humanity will take recourse to increased recycling to fill the gap and that technology will evolve further to enable extraction and upgrading of low grade PR deposits. While these mechanisms are obviously important, there currently appears to be insufficient knowledge available on the sources of future reserves and resources to solely rely on these mechanisms.</p> <p>The reviewers state that PR is not a "fixed pie". We do not agree. High grade deposits of PR have formed under circumstances which are rare in time and space (Filipelli, 2011) as they require favourable paleoceanic, palaeographic, paleoclimatic and other factors to coincide (Orris and Chernoff, 2004). From a civilizational timescale, PR deposits are a finite resource. Once dispersed into the aquatic system, it is currently not possible to re-concentrate P. While mining improvements and recycling will slow down the consumption date, extraction from PR sources implies that the quantity of available PR will diminish and that the quality will decrease further. For instance, Van Kauwenbergh (2011) states that in the future, PR deposits may be smaller, deeper, at greater distances from coasts, lower in grade and/or in more challenging environments, and that available reserves may dictate lower grade fertilizer products.</p>
2	<p>Further, URR if we refer to mineable phosphate ore is not a known or currently well accessible number. The report of Orris & Chernoff (Orris & Chernoff, 2004) identifies about 1600 phosphate deposits and occurrences in over 80 countries. Most of these deposits and occurrences are poorly assessed. The potential of offshore deposits are not discussed.</p>	<p>We reviewed the Orris and Chernoff paper as part of our literature review. The paper includes minor PR accumulations, guano deposits and other deposits of minor importance. Van Kauwenbergh, 2006, p. 41, states the following about the term "deposit":</p> <p><i>"By definition, a deposit is "earth material of any type either consolidated or unconsolidated that has accumulated by some natural process or agent (Bates and Jackson, 1980). The term "deposit" does not imply that phosphate exists in a form, quantity, or quality that is technically or economically feasible to produce. The average abundance of P₂O₅ in the earth's crust is 0.22 wt% (Carmichael, 1982). A concentration of 1.0% P₂O₅ is certainly anomalous and therefore can be termed a deposit."</i></p> <p>Orris and Chernoff do not discuss the economic potential of any of the deposits they entered into their inventory, nor do</p>

		they detail the quantity that could be extracted. It is interesting to know that there are 1600 PR deposits, but it adds little to our knowledge as to potentially viable PR. To place the data in perspective, again, further research is required as to the major deposits which are currently not included in the resources and their potential for future extraction.
3	<p>The proposed notion of sustainability does not ask for “infinite “reserve growth” but for progressively closing the phosphorus cycle and taking less so that the reserves will not fall below a certain amount (e.g. measured by lifetime as a vulnerability indicator). And as, we have noted, the URR is not a fixed entity such as a pie on a table.</p> <p>What we will know in 400 years about reserves, mining and recycling and what is economically mineable may be certainly much higher.</p>	<p>The reviewers argue that sustainable use of PR entails a progressive closing of the P cycle. We fully agree with this statement and add a correction to the paper to make sure that the reviewers' views on this issue are adequately reflected where discussing Scholz and Wellmer, 2013.</p> <p>The reviewers also state that use may be sustainable as long as reserves do not fall below a certain amount, as measured by a "vulnerability indicator". Earlier in the review, Scholz and Wellmer indicated that the Reserve/Consumption ratio could be a useful yardstick for this. Given the dynamics of reserves and the essentiality of PR for humanity, we doubt whether the R/C ratio is a relevant indicator. If reserve data are to be used for this purpose, this underlines the need for transparent and reliable data on reserves and resources.</p>
	Further research	
	Scholz and Wellmer	Response
1	<p><i>The authors state at the end of the Abstract “Further research is required as to the quantity of PR deposits and their viability for future extraction”.</i></p> <p><i>We are in full agreement with this statement. The aim of the Global TraPs project is to improve transparency as an element of supply security with the following elements</i></p> <p><i>a) monitoring of material flows</i></p> <p><i>b) improving the understanding of the dynamics of reserves and resources.</i></p> <p><i>c) better understanding of the geopotential as a source of future reserves (here an excellent base to continue is the IGCP-project 156: Phosphate deposits of the world from 1977 to 1988 (Cook & Shergold, 1986))</i></p> <p><i>d) understanding learning curves for future PR supply”.</i></p>	<p>The reviewers agree that further research is required as to the quantity of PR deposits and their viability for future extraction and state that the aim of the Global TraPs project is to improve transparency as an element of supply security. However, rather than discussing the research questions, the reviewers appear to promote their own research agenda. Monitoring material flows (sub (a)) is interesting and may help to analyze PR consumption and recycling options. However, it has nothing to do with data reliability. Focusing on dynamics of reserves and resources (sub (b)) seems to contribute little to an understanding of the deposits which could potentially be exploited. We understand that with "learning curves for future PR supply" mentioned under (d), the reviewers refer to modelling to extrapolate increasing mining efficiencies which will occur as high grade PR deposits will become scarcer. Again, while undoubtedly of interest, this has no direct relation with the issues of data reliability addressed in our paper.</p> <p>Sub (c), fostering a "<i>better understanding of the geopotential as a source of future reserves</i>" appears to coincide with our recommendation and if so, we welcome this.</p> <p>The reference to the IGCP-project 156 and Cook and Shergold, 1986, may suggest that we would not have noted this project and the literature which emanated from it. Such suggestion would be incorrect. The Unesco/ IGCP Project 156 issued three volumes: the first (Cook and Shergold, 1986) deals only with Proterozoic-Cambrian Phosphorites which were formed in one of the early phases of phosphogenesis as this was the class of which the least was known scientifically (Cook and Shergold, 1986 p. xiv). The second volume – Notholt et al. (1989), which we cited extensively in respect of a number of countries (Iraq (Al Bassam, 1989), USA (Sheldon, 1989, discussing the WPF), Morocco (OCP, 1989)) – dealt with the identification of PR resources on a global scale. The third and last volume dealt with the processes by which PR deposits are formed. A fourth working group which investigated the economically very important Cretaceous-Eocene phosphorites (which includes the Moroccan deposits) never resulted in a publication.</p>

Additional references:

- Australian Government. (2011). Australian Mines Atlas. Retrieved December 19, 2013, from <http://www.australianminesatlas.gov.au/aimr/commodity/phosphate.html>
- Cook, P. J., & Shergold, J. H. (1986). Phosphate Deposits of the World. Cambridge: Cambridge University Press
- Filippelli, G.M., 2011. Phosphate rock formation and marine phosphorus geochemistry: the deep time perspective. *Chemosphere* 84, 759–7
- Lambert, I., Mieziotis, Y., Carson, L., & McKay, A. (2012). National reporting of identified mineral resources in Australia: How it draws on, but differs from, company reporting. Retrieved December 19, 2013, from http://www.unece.org/fileadmin/DAM/energy/se/pp/unfc_egrc/egrc3_may2012/2May/4_5_Lambert_al_NR.pdf
- Orris, G. J., & Chernoff, C. B. (2004). Review of world sedimentary phosphate deposits and occurrences. In J. R. Hein (Ed.), *Handbook of Exploration and Environmental Geochemistry*. Vol. 8. *Life Cycle of the Phosphoria Formation - From Deposition to the Post-Mining Environment* (pp. 559-573). Amsterdam: Elsevier.
- Rustad, J. R. (2012). Peak Nothing: Recent Trends in Mineral Resource Production. *Environmental Science and Technology*, 46, 1903–1906.
- Scholz, R. W., Roy, A. H., & Hellums, D. T. (in press). Sustainable phosphorus management: a transdisciplinary challenge. In R. W. Scholz, A. H. Roy, F. S. Brand, D. T. Hellums & Ulrich A. E. (Eds.), *Sustainable phosphorus management: a global transdisciplinary roadmap*. Berlin: Springer.
- Van Kauwenberg, S.J.: Use of phosphate rocks for sustainable agriculture. *FAO Fertilizer and plant nutrition bulletin* 13, FAO, Rome 2004.