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THE MILLENNIUM OF RUSSIA'S FIRST PERESTROIKA: THE ORIGINS OF A KIEVAN GLASS INDUSTRY UNDER PRINCE VLADIMIR

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Introduction

The title of this paper was very carefully selected to emphasize several important points. First, much of the discussion about Gorbachev's policies for *perestroika* leaves the distinct impression that the current program of economic restructuring constitutes an unprecedented, unique effort at economic reform. Some experts occasionally remember the economic reforms of the New Economic Policy in the early 1920s and even the economic reforms resulting from the 1905 revolution. A very small number of specialists even recall the great reforms of Alexander II in the 1860s and early 1870s. Nevertheless, it is abundantly clear that the vast majority of specialists focus all their attention on today's events and tomorrow's possibilities and thus fail to consider that major economic and related reforms have a very long history among the East Slavs. One only need mention Peter the Great in the early eighteenth century, the young Ivan the Terrible in the 1550s, and Grand Prince Vladimir Monomakh in the early twelfth century, a ruler whose reforms were even likened to Franklin Roosevelt's New Deal. Rather than being unique, Gorbachev's *perestroika* is merely the most recent expression of the periodic attempts to reform Russia's economy--attempts which can be traced back to the pre-Mongol era.

Given these circumstances, it seems that we must adopt a much broader perspective on current Soviet economic changes. If we temper our obsession with the present, we can begin to examine the cyclical patterns of economic reform with much greater insight and perspective. Instead of viewing each effort at rapid economic development as an isolated series of events, we can explore the process of economic change in Russia as it has manifested itself

over a thousand years. For example, we can consider such issues as the extent to which economic development in Russia has consistently depended upon technology transfer from abroad, whether state initiative has proved to be more successful than private activity in promoting economic growth, and the nature of the noneconomic reforms that are necessary for enhanced economic development.

This emphasis on perspective and process does require some major changes in the way we prepare Russian and Soviet specialists. For too long, pre-nineteenth century Russian history has been either ignored or given cursory and superficial treatment. I have been told by reliable sources that early Russian history is sometimes taught as a series of jokes and anecdotes and, even in some of our best graduate programs, medieval Russian history is not offered at all. We would never teach American Studies by ignoring our own Revolution and our bitter Civil War and starting ca. 1900. But we apparently believe that we can do this in Russian Studies.

The first major era of rapid economic growth in the history of the East Slavs was brought about by St. Vladimir's conversion to Orthodoxy. Thus, when we celebrate the millennium of Russia's conversion, we are also celebrating the first recorded effort by an East Slavic ruler to restructure the society which he governed, a restructuring which had important economic consequences.

Most studies of St. Vladimir's conversion emphasize that it brought religion, culture, and art to Russia. However, without minimizing the importance of religion, culture, and art in any way, the second point that the title of this paper tries to make is that the conversion of St. Vladimir to Orthodoxy had important economic ramifications for Kievan Rus'. I think we can all understand the far-reaching political implications of conversion.

Orthodoxy became the cement holding together St. Vladimir's heterogeneous peoples and Orthodoxy also legitimized St. Vladimir's rule over them. Vladimir was God's anointed ruler over diverse peoples who were now to be united by adherence to Orthodoxy. The economic consequences of Vladimir's conversion, while equally far-reaching, are much less obvious and have thus far been largely ignored. Nevertheless, conversion was the catalyst for the rapid economic growth of several key industries in early Rus'.

To understand this basic relationship between religious conversion and economic development it is perhaps best to begin with Kievan Rus' in the century and a half before the Mongol invasion, roughly from 1100 to 1240. Archeological excavations of numerous towns of this era located all over the Rus' lands have unearthed large quantities of manufactured goods made in Kiev. Among the many goods produced in Kiev and exported throughout the Rus' lands, glass items are the most prominent. There is no doubt that hundreds of thousands of glass beads, glass bracelets, glass rings, various glass vessels, and small glass windowpanes were made in the workshops of Kiev for use throughout the Rus' lands. Thus, several years ago I began to explore the questions of when, why, and how Kiev became one of the major centers of glass production in Western Eurasia during the pre-Mongol era. This paper presents the results of one key part of this research.

A Brief History of Glassmaking in Kievan Rus'

For a long time it was believed that all the glass found in pre-Mongol Rus' sites was imported, primarily from Byzantium and the Orient.[1] This older and long outdated view unfortunately persisted long after it had been disproved.[2] In fact, glass workshops of the pre-Mongol era had already been discovered in

Kiev by V. V. Khvoika in 1907-1908.[3] At present, Soviet archeologists have identified a significant number of workshops throughout the Rus' lands where glass and glass products were made during the Kievan era. In Kiev alone, eight glass workshops from the pre-Mongol period are now known.[4] A number of other workshops producing glazed tiles, glazed ceramics, inlaid enamel, and other goods connected with glass production also existed. Thus, there is no doubt that glass was produced in large quantities throughout the Rus' lands during the eleventh to thirteenth centuries.

Since World War II, the scientific analysis of medieval glassware has revolutionized our knowledge of the glass used in Kievan Rus'. In particular, we should note the many important studies of Mikhail Alekseevich Bezborodov and Iuliia Leonidovna Shchapova.[5] Based on these studies, Soviet specialists have been able to trace with considerable precision the origins and development of glassmaking in Rus' during the Kievan era. To facilitate our discussion here, some of Shchapova's key findings have been graphically portrayed in Table A.[6]

According to Shchapova, Rus' glass was probably first produced in the capital city of Kiev shortly before the year 1000. More specifically, this development is connected with the invitation extended by the newly converted Grand Prince Vladimir to Greek masters to build and adorn his new Church of the Tithe.[7] Presumably then, it was the manufacture of mosaics and/or tiles for the Church of the Tithe during the 990s by Byzantine masters which initiated a glass industry in Rus'. Shchapova has thus argued that Rus' glassmaking was unquestionably connected with Byzantium and, while indigenous Rus' glassmaking diverged in some key ways from its Byzantine roots, it owed much to the Greeks.[8]

Table A

The Origins and Development of Glassmaking in Kievan Rus'

Year	Greeks in Kiev	Rus'	Rus'
1000	NaKCaSi/beads mosaics, bracelets	PbSi/Kiev/ beads, rings	
1025	*	*	KPbSi/Kiev/ glassware, window glass, beads, rings
1050	rings, vessels, window glass	declining production	increasing production
1075	*	*	*
1100	*	Kiev/glazing for ceramics, tiles, *pisanki;* smalt for mosaics	*
1125	*	*	Kiev/bracelets Kiev/new types of glassware
	*	Kiev/bracelets (briefly), Liubech/ bracelets	*
1150	* * *	Novgorod/ bracelets Smolensk/ bracelets Polotsk/ bracelets	* * *
1175	sharp decline in production--some bracelets made	*	*
	*	Voishchiny/ bracelets	*
	*	*	increasing production
	*	*	*
	*	*	Novgorod/Old Riazan'/Serensk/
1200	*	Production of *pisanki* ceased	bracelets, beads?, rings?
1225	*	*	*

According to Soviet scholars, two schools of glassmaking developed in Rus'. One was formed by Greek masters working in Kiev. This Greek school used a variant of the traditional soda-lime-sand recipe whose basic chemical components were NaKCaSi (sodium-potassium-calcium-silicon). The Rus' school, which developed first in Kiev and then spread elsewhere, utilized a recipe whose chief chemical components were PbSi (lead-silicon) or KPbSi (potassium-lead-silicon). In other words, Soviet scholars such as Shchapova assert that the chemical composition of medieval glass reveals the ethnic origin of its makers or, at least, the tradition from which they came.[9]

The Greek glassmakers, who used a variant of the classical Mediterranean-Near Eastern recipe, first appeared in Kiev during the late tenth century. They made the smalt used for mosaics in the early Rus' churches. The tailings from this activity were also employed to produce glass beads and bracelets. Around the mid-eleventh century, the Kievan Greeks also started to produce glass rings, vessels, and window glass. During the 1170s-1180s, their glass production declined sharply due to successful competition from Rus' glass-makers and political problems within Rus'. As a result, the manufacture of high quality vessels, window glass, rings, and beads almost ceased. However, from the 1180s until the Mongol conquest of 1240, some Kievan Greeks continued to make glass bracelets. The Mongol conquest put an end to their glassmaking. Overall, the glassware made by these Kievan Greeks accounted for only a very small percentage of the glass produced in Kievan Rus'.[10]

Much attention has been devoted to the indigenous Rus' school of glass making and its evolution. The earliest Rus' glassmakers appeared in Kiev around the year 1000, making beads and rings from a PbSi recipe. Some time around 1025, Rus' masters in Kiev began to produce glassware, window glass,

beads, and rings using a KPbSi recipe. The KPbSi glass apparently proved superior to the simpler PbSi glass, and it captured a larger and larger part of the growing eleventh-century glass market. Thus, by the early twelfth century, beads, and rings made of PbSi glass were disappearing within Rus'. However, this type of glass was saved from extinction by two developments. First, around the year 1100, PbSi glass began to be used for the glazing of ceramics, tiles, and *pisanki* (glazed ceramic eggs), as well as for the smalt from which the increasingly popular mosaics in churches were made. Then, around the 1130s, Kievan masters of the PbSi recipe began to produce glass bracelets. The boom in church construction as well as the huge market for glass bracelets in the Kievan towns guaranteed the continued production of Rus'-made PbSi glass until the Mongol conquest.

Glass of the tripartite KPbSi recipe became dominant in Rus' during the eleventh century and retained its leading position until the mid-thirteenth century. Like the PbSi glass, it evolved and grew over time. Around 1125 or so, bracelets of KPbSi Glass were first made in Kiev and they soon became an item of mass production. While large numbers of bracelets were made from PbSi glass, spectral analysis of bracelets from various Rus' sites suggests that many more were produced from KPbSi glass. Then, during the second quarter of the twelfth century, new types of glassware made in Kiev using the KPbSi recipe were introduced. Furthermore, production of both glassware and window glass seems to have grown during the twelfth century. Both goods were made only in Kiev using the KPbSi recipe.

A major new development in the history of early Rus' glassmaking started in the 1130s when glass was first produced outside of Kiev. Around this time, bracelets of PbSi glass were made for a short time in Liubech north of Kiev

along the Dnepr River. By 1150 or so, production of glass bracelets using the PbSi recipe began in Novgorod. By about 1175, PbSi glass bracelets were being made in Voishchiny near Smolensk, as well as in Smolensk and Polotsk. Thus, the technology of making simple PbSi glass bracelets to supply strong local demand was transferred from Kiev to several provincial centers starting in the mid-twelfth century. Or, to be more precise, by the mid-twelfth century masters of PbSi glass from Kiev had begun to set up business in some of the other towns of Rus'. Kiev's 150-year monopoly over glass production within Rus' had come to an end.

Just as the secret of the simpler PbSi glass spread from Kiev to other towns in Rus', production of the more complex KPbSi glass was also diffused from Kiev to other parts of Rus'. By the late twelfth and early thirteenth centuries, KPbSi glass was being made in such major towns as Novgorod and Old Riazan' as well as in Serensk along the upper Oka. Thus, by the early thirteenth century, masters of both types of indigenous Rus' glass recipes had moved from Kiev to an increasing number of towns throughout the Rus' lands.[11]

Finally, we must emphasize the tremendous quantity of glass objects made in Rus' during the pre-Mongol era. Some years ago, Shchapova estimated that over 30,000 glass bracelets alone had been found in various Kievan towns.[12] This estimate is very much out of date now, as new excavations and studies have revealed a much larger number of glass bracelets from an ever growing number of Kievan sites. And if we add to this figure the many thousands of fragments of glassware, window glass, glass beads, and glass rings now known from various Rus' towns, we are talking about glass production of hundreds of thousands of fragments in the Kievan era.

While many of these fragments no doubt came from the same objects, only a

relatively small part of the total area of Kievan towns has been excavated. Thus, there is no reason to doubt that Rus' masters produced hundreds of thousands of glass objects during the pre-Mongol era.

The Role of Greeks and Rus' in Kievan Glassmaking

The above summary of Soviet scholarship raises two fundamental questions concerning the origins of glassmaking in early Russia. First, is it true that Greek and native Rus' glassmakers worked independently in Kiev for over two centuries? Following the introduction of glassmaking into Rus', one can envision a transitional era during which the two traditions--one foreign and one local--coexisted side-by-side. But it is much harder to believe that a few Greeks in Kiev maintained the Byzantine tradition, independent of the local Rus' tradition, for some two hundred years. Shchapova's ethnic taxonomy of glassmaking in Kievan Rus' needs to be examined critically. Secondly, why did the Rus' adopt a glassmaking formula which was so different from that used in Byzantium? Presumably, the Rus' would have borrowed the Byzantine recipe for glass when they learned the secret of glassmaking from Byzantine masters. The Soviet argument that the early Rus' glass industry did not employ the Byzantine recipe for making glass must be analyzed carefully. In sum, these two key issues need to be addressed in order to understand the origins of the glassmaking industry in Rus'.

Let us begin with the first question. The Byzantine glassmakers working in Kiev supposedly employed the "traditional" soda-lime-silica recipe for glass used in the ancient and medieval Mediterranean worlds. In this traditional recipe, sodium-calcium-silicon (NaCaSi), sand (silica, silicon dioxide, or SiO_2) was combined with a soda fluxing agent (sodium oxide, or Na_2O)

designed to lower the temperature at which the glass could be worked. Lime (calcium oxide, or CaO), which was perhaps added accidentally as a constituent of the sand and/or soda, improved the durability of the glass and, like soda, also acted to lower its viscosity.[13] Thus, it is reasonable to assume that the first Greek glassmakers to arrive in Kiev brought with them this traditional NsCaSi recipe.[14]

In Kiev, these Greek masters supposedly produced a NaKCaSi (sodium-potassium-calcium-silicon) glass.[15] The presence of potassium (K) in this purported Greek glass from Kiev is perhaps best explained by the fact that plant ash was a major source of alkali in ancient and medieval glassmaking. While the ash of coastal plants--that is, those from the shores of the Mediterranean--has a high sodium content, the ash of continental plants has a high potash (potassium carbonate, or K_2CO_2) content.[16] Consequently, it is likely that Greek glassmakers in Kiev, following long established Mediterranean practices, would seek soda in the ashes of the local plants which also happened to contain a significant potash component.[17] Alternatively, the raw materials imported by Greek glassmakers into Kiev from the Mediterranean or Black Sea happened to contain a significant potash component.[18] It is to be hoped that Soviet scholars interested in the scientific analysis of glass may be able to identify those plants of the middle Dnepr or Black Sea regions whose ashes would produce a glass like that made by the supposed Byzantine masters of Kiev.

The so-called native Rus' school of glassmaking initially developed in Kiev soon after the first Greeks began to produce glass there. Unlike the Byzantines, however, the Rus' glassmakers allegedly utilized PbSi (lead-silicon) and KPbSi (potassium-lead-silicon) recipes. There is a tendency

among some Soviet scholars to imply that these two recipes were unique to Rus'. In fact, as Bezborodov has clearly shown, PbSi glass (actually $mPbO\text{-}nSiO_2$) was produced in Japan during the eighth century and has been found in Poland from the ninth to thirteenth centuries,[19] while KPbSi glass (actually $mK_2O\text{-}nPbO\text{-}pSiO_2$) appears in ninth-tenth century Indonesia as well as in twelfth-thirteenth century Poland.[20]

Lead silicate glass has a long history, probably going as far back as Babylonia ca. 1700 B.C.[21] The reasons for the widespread popularity of such glass can be explained by the fact that lead both lowers the melting point of glass and increases its stability. In addition, lead, like silica, can serve as a glass former.[22] Consequently, various peoples in various places have utilized lead as a major ingredient in glassmaking ever since ancient times.[23] However, much of this lead glass was historically connected with glazing and enamelling.[24] In any event, the appearance of a lead silicate glass in Kiev around the year 1000 is far from being a unique development in the history of glassmaking.

It is also very understandable why Rus' glassmakers began to add potassium to their lead silicate recipe. As Biek and Bayley have noted, a mixture of about 30 percent lead with potash in a silicon-based glass produces a "white" glass with a "remarkable combination of properties relating to mechanical workability and stability on the one hand, and brilliantly sparkling clarity and aesthetic appeal on the other...."[25] Not surprisingly, most of the KPbSi glass from Rus' and much of this type of glass from medieval Indonesia and Poland contain around 20-30 percent lead oxide.[26] The Rus' glassmakers thus discovered what other medieval glassmakers had also learned regarding the benefits of adding potassium to a lead-silicate glass.

The KPbSi glass from Rus' must be placed in a broader European context. Between 800 and 1000 A.D., a major change took place in the composition of the glass made in Central and Western Europe north of the Alps. While the medieval Mediterranean world continued to utilize the traditional soda-lime-silica recipe, the glassmakers of Northern and Central Europe began to use potash as a fluxing agent.[27] The potash glass made in medieval Western Europe also contained a significant percentage of lime so that its basic components were KCaSi with magnesium and/or aluminum also appearing in significant amounts in some of this glass.[28] This switch from a soda to a potash glass apparently took place when the glassmakers of medieval Western and Central Europe ceased their reliance upon imported natron and/or plant ash from the Mediterranean and instead began to use the ash of local beechwood, which was rich in potash.[29] It has been suggested that the growing demand for window glass in Western European churches and cathedrals starting in the ninth century created a shortage of imported soda ash from the Mediterranean coasts and prompted the glassmakers north of the Alps to turn to local beechwood for their ash.[30] Thus, the appearance of potassium in early Rus' glass can be viewed as part of the overall change in medieval continental Europe from a soda to a potash glass.[31]

The presence of calcium/lime in the medieval Western European potash glass and its paucity in the potash glass from Rus' could be interpreted as evidence that medieval Western European glass was quite distinct from Rus' glass. However, it is not clear to what extent this difference was deliberate or merely the chance result of variations in the content of locally available raw materials. Turner, for instance, demonstrated that lime (CaO) was a natural constituent of the sand and/or alkali used in glassmaking and was *not* added to

the recipe intentionally.[32] Therefore, the presence of a significant calcium component in medieval Western European glass was apparently the consequence of a significant soda component in the ashes of those plants and trees which, like beechwood, were used to obtain potash. The absence of a large calcium component in the Rus' potash glass was perhaps the result of the small lime content in the ashes of those plants and trees used by Rus' glassmakers to obtain potash. Otherwise, we would have to assume either the deliberate addition of lime to medieval Western European glass or the deliberate elimination of lime from Rus' glass, or both. Since such assumptions are not very credible, it appears best to view the Rus' KPbSi glass as one variant of the potash glass made north of the Alps starting ca. 800-1000 A.D.. As a working hypothesis, we can attribute the differences between Rus' potash glass and medieval Western European potash glass to differences in the chemical composition of the ashes of the plants and trees used to obtain potash in various parts of continental Europe.

It should be emphasized here that the analysis of medieval glass based on its chemical composition is a very complex question. Due to the vagaries of medieval glassmaking, the study of this glass cannot be considered an exact science producing definitive answers. Rather, it can suggest patterns, only part of which can be explained satisfactorily. The scientific examination of the glass from any single site, for instance, usually reveals the existence of a large number of different recipes, some of which were probably only experimental. Thus, in her study of the mosaic tiles from the Uspenskii Sobor (the Cathedral of the Dormition of the Virgin or Assumption of Mary) in Kiev, Shchapova enumerated *eleven* different glass recipes among just eighty-nine finds of glass studied.[33] A significant number of distinct glass recipes have

also been reported from other Rus' sites. While a few recipes were usually predominant, it is clear from this diversity that medieval glassmakers did not employ a highly standardized technology to work uniform batches of purified raw materials. Instead, they were never quite certain of the variations or impurities to be found in any batch of glass and each batch was thus processed under imperfect conditions until a more or less satisfactory glass resulted.

The exact contents of key ingredients such as sand or beechwood ash could also vary significantly. This was true for the same source at the same time, for different sources at the same time, for the same source at different times, and for different sources at different times. While medieval glassmakers knew the consequences of using many components, they could never be certain how much of a desired component was present in their raw materials nor did they possess the technology to work these chemicals in the most effective manner. In fact, it was not until the seventeenth century that the difference between the two main fluxing agents, soda and potash, was discovered.[34] It was only in the late seventeenth century that the importance of deliberately adding lime to a glass batch was clearly understood.[35] The working of impure raw materials using an imperfect technology with a trial and error approach created a situation in which the diversity of recipes revealed by modern analysis is hardly surprising. Consequently, as Frank wisely cautions, the conclusions drawn from glass analysis must be "very circumspect and...limited in scope" since much harm can be done through the creation of great theories based on inadequate scientific evidence.[36]

The above circumstances suggest that it would be wise for us to treat Shchapova's hard and fast distinction between two different schools of early Rus' glassmaking with some caution. The problems presented by the mosaics

from the Uspenskii Sobor in Kiev, built ca. 1080, illustrate why Shchapova's ethnic taxonomy may be a little too simplistic. Shchapova, for instance, identified sixteen examples of NaKPbSi glass which represented eighteen percent of the total sample studied (eighty-nine pieces of glass). This glass is particularly interesting because it does not fit any of Shchapova's standard "Greek" or Rus' recipes. The Greeks in Kiev supposedly used a modified version of the traditional recipe which had calcium (Ca) as one of its key components. The low percentage of calcium along with the presence of lead in this glass group would thus argue against its "Greek" origin. Rus' glass, on the other hand, is supposedly characterized by a low percentage of soda (Na). The presence of a large sodium component in this group of glass would thus argue against its Rus' origins. To resolve this dilemma, Shchapova looked at the "secondary" characteristics of these sixteen examples. She assumed that the deliberate addition of manganese oxide (MnO) as a decolorizing agent to a batch was a Greek practice kept secret from Rus' masters. Consequently, the seven examples of the NsKPbSi glass without manganese were attributed to Rus' glassmakers while the nine examples with manganese oxide were said to have been made by the Greeks working in Kiev.[37]

Shchapova's interpretation of the NaKPbSi glass illustrates the dangers of trying to draw clearcut ethnic conclusions from limited and imperfect data. There is *no hard evidence* that Greek glassmakers in Kiev intentionally added manganese as a decolorizing agent or that they kept it a secret from the Rus'. In fact, as Shchapova herself noted, a relatively high level of manganese oxide is found in some, but not all, Bulgarian glass and this apparently helps to distinguish Bulgarian glass from Byzantine glass.[38] We can thus conclude that either the Byzantines shared this secret with the Bulgarians but

not with the Rus' or, more probably, that the raw materials used to make glass in Rus', Byzantium, and Bulgaria might contain varying quantities of manganese oxide about which the glassmakers did not necessarily have any knowledge.

Since manganese was apparently present in varying quantities in all examples,[39] it may well be that the presence or absence of significant quantities of manganese in any glass batch was simply an accidental by-product of the primary raw materials. For example, in a study of Babylonian NaCaSi glass of ca. 250 B.C. from Nippur, the percentage of manganese oxide varied between .41 percent and 5.92 percent.[40] As Turner has noted, "Manganese oxide is clearly a widespread constituent of ancient glasses,"[41] and he further commented that we do not know when manganese was first added to glass as a specific ingredient since the "first certain literary references to manganese [in treatises on glass] do not occur until Renaissance times."[42] Thus, Shchapova's basic assumption about the attribution of the NsKPbSi glass from Kiev can be called into question.

In addition, if Shchapova is correct about the manganese, then we would possess definite evidence that Greeks in Kiev made a glass with a significant lead content and no significant lime content, while Rus' masters made a glass with a high soda content. In other words, Shchapova's analysis shows the Greeks of Kiev employing distinctly "Rus'" ingredients like lead, while the Rus' were using distinctly "Greek" ingredients like soda.

The discussion of the significance of small quantities of manganese in various glasses tends to obscure a far more important point. If Shchapova is correct, then Greek and Rus' glassmakers in Kiev used the *same basic recipe* to make a significant number of the mosaics from the Uspenskii Sobor. And, if Greek and Rus' masters could both use the same formula to manufacture many of

the mosaics, why is it inconceivable that Rus' glassmakers would employ the so-called ancient recipe or that Byzantine glassmakers would use the so-called Rus' recipes?

The blurring of Shchapova's ethnic taxonomy is also reflected in other types of glass from the Uspenskii Sobor. There were, for instance, four examples of a NaKMgCaPbSi glass. While possessing characteristics of both the ancient and Rus' recipes, Shchapova connected this glass with the Greek masters of Kiev primarily because of its manganese content.[43] But, as noted above, the manganese content is not necessarily a reliable indicator of ethnicity. Thus, we again have either Greeks making a lead glass like the Rus' or the Rus' making a soda and lime glass like the Greeks, or both.

To further complicate matters, we have one piece of KMgCaPbSi glass from the Uspenskii Sobor which Shchapova attributed to the Rus' masters due to its minuscule manganese oxide content.[44] If we assume that Shchapova is correct, this example would again demonstrate that Rus' masters made glass containing significant quantities of lime. This conclusion is further strengthened by Shchapova's attribution of another slightly different piece of glass (KCsMg-PbSi) to the Rus'.[45]

The single piece of KCaMgSi glass from the Uspenskii Sobor is, as Shchapova states, similar to medieval Western European glass. But Shchapova rejects any connection between this piece and Western European glass since the latter was supposedly characterized by phosphorus oxide, which is not present in the Kiev glass. Thus, Shchapova ends up by grouping this piece of potash glass with variants of the ancient recipe (NaCaSi),[46] a decision which clearly violates Shchapova's fundamental principle that during the Middle Ages the chemical composition of glass reveals the origin of its makers.[47] Surely this

example of potash glass should be linked with Europe north of the Alps, whether East or West.

An examination of Bezborodov's tables for KCaMgSi glass shows that this glass has been found in Uzbekistan during the tenth-twelfth centuries, in Czechoslovakia during the eighth-ninth centuries, in Kalinin or Tver along the upper Volga in Russia during the eleventh-thirteenth centuries, and in North Germany ca. 1000, as well as in Kiev and Vyshgorod during the eleventh-thirteenth centuries. The examples from Uzbekistan, Czechoslovakia, Tver, and Kiev did not contain any phosphorus oxide (P_2O_5), while those from Vyshgorod in Rus' and North Germany did.[48] Therefore, phosphorus was not always present in medieval Western European potash glass either in the pre-Mongol era or later.[49]

The KCaMgSi glass from the Uspenskii Sobor was thus presumably made either by an itinerant West European glassmaker or by a local Rus'/Greek glassmaker who may have been familiar with a West European variant of potash glass. Alternatively, a local master preparing a batch of potash glass happened to obtain either local or imported ash containing lime and magnesium oxide. There is no evidence that an itinerant West European glassmaker stopped in Kiev, produced a few pieces of KCaMgSi glass, and then moved on. It is more probable that local glassmakers simply simulated the West European potash recipe and, for some reason, found it less satisfactory. And, finally, it is most likely that local glassmakers received some potash ashes, perhaps imported, which differed in composition from the ashes normally used.

The one piece of PbCaMgSi glass from the Uspenskii Sobor further confuses Shchapova's ethnic taxonomy of Kievan glass. This fragment differs from Rus' lead silicate glass due to the presence of significant quantities of lime and

magnesium--elements which were characteristic of Byzantine and West European glass. On the other hand, lead glass was supposedly not characteristic either of Byzantium or medieval Western Europe. Shchapova has apparently placed this example among the Rus' glasses because of its lead silicate component.[50] However, if this is correct, it would show that Rus' glassmakers did use lime and magnesium.

To explain the many puzzles of the glass from the Uspenskii Sobor, Shchapova postulated that the mosaics in this cathedral were done by both Greek and native Rus' masters.[51] She admits that there was some interaction in this cooperative endeavor: the Greeks apparently learned about the advantages of lead silicate glass from the Rus', while the Rus' tried some of the raw materials employed by the Greeks. Despite these close contacts, however, Shchapova insists that the Rus' and Greeks worked independently of each other and, although they were willing to experiment, each remained true to their own glassmaking traditions. In other words, neither could find anything of permanent value in the recipes of the other, and each school continued to go its own separate way.

In addition to the above technical considerations, Shchapova's ethnic taxonomy asks us to believe that for two and a half centuries (ca. 1000-ca. 1240) a small number of Greek masters resided in Kiev where they produced glass using a variant of the ancient Mediterranean recipe and assiduously guarded various secrets. Furthermore, this took place while the ancient recipe was unable to compete with the highly successful KPbSi glass and the supposed Byzantine secrets were obtained and used by the Bulgarians and others.

At the risk of seeming brash, I would like to propose a very different

scenario for the role of Greeks and Rus' in the development of glassmaking in the Kievan era. Glassmaking was definitely introduced into Rus' by the Greek masters who were invited to work on the mosaics and glazed tiles which decorated several of the great churches of Kiev, built during the century or so after the conversion of Rus'. As we have seen, the participation of Greek masters in the construction of these churches is specifically mentioned by Rus' written sources.[52] Thus, prior to the twelfth century, Greek glassmakers had already been invited to Kiev on several different occasions to decorate important churches with mosaics and glazed tiles.

But, as a leading Soviet specialist, V.N. Lazarev, has pointed out, the Rus' chronicles only recorded five cases of Greek artists coming to work on Rus' churches during a period of over five hundred years, and most of these cases dated from the post-Kievan era.[53] Furthermore, the number of Byzantine masters invited to help decorate any one Rus' church was not great. It has been estimated, for example, that around eight Byzantine mosaicists worked on the Church of St. Sophia in Kiev[54]--the greatest church of the early Kievan era. Finally, we have evidence of only one instance in which the Greek masters invited to Rus' actually remained there. The highly didactic *Paterikon*, which recorded the lives of the monks of the Pechersk Lavra in Kiev, stated that the Greek masters from Constantinople who had helped to construct and adorn the Uspenskii Sobor did not return to Greece but instead remained in Kiev, where they died and were buried.[55] For this and other reasons, Lazarev suggested that the Greek masters who worked on the Uspenskii Sobor may also have worked on the Church of the Archangel Michael built in Kiev ca. 1108.[56]

On the other hand, Lazarev also argued very strongly that the workshop of the masters who worked on the Church of St. Sophia in the 1040s was in no way

connected with the workshop used to decorate the Uspenskii Sobor in the 1080s.[57] In other words, the evidence indicates that no continuity existed between the visiting Byzantine masters of the 1040s and those of the 1080s. Indeed, if Byzantine glassmakers had been established in Kiev since the 990s, as Shchapova argued,[58] then it is not clear why four Greek masters had to be especially invited to adorn the Uspenskii Sobor a century later. The glass-making workshop uncovered near the Uspenskii Sobor, which only functioned during the late eleventh century, strongly suggests that, once a major church project was completed, the related glassmaking workshop was shut down and the masters as well as their pupils had to find other employment in Kiev or move elsewhere. Thus, we find that relatively few Byzantine glassmakers ever came to Kievan Rus' and, of these, only a handful ever stayed. Most Greek masters seem to have finished their commissions in Kiev and then returned home. Under these circumstances, it is very hard to believe that a "Greek" school of glassmaking existed in Kiev for over two hundred years.

At this point, it is important to mention Lazarev's conception of Rus'-Byzantine cooperation in the areas of mosaics and murals. His conception of these relations differs greatly from that of Shchapova and thus provides a quite different context for reconstructing the origins of the Rus' glass industry. Lazarev characterized the activities of the Greek artists who came to Rus' in three key points: 1) there are few instances of Greek artists coming to Rus'; 2) the Byzantine artists who did come usually cooperated with local Rus' artists; and, 3) the Byzantine artists in Rus' nearly always instructed the young Rus' artists.[59] In other words, Lazarev's view of Rus'-Byzantine interaction emphasizes a cooperative relationship in which the Rus' learned from the Greeks while both worked together on the same projects.

This positive view contrasts sharply with Shchapova's somewhat negative conception, which has Byzantine masters working separately from the Rus' and carefully protecting their "secrets" from Rus' masters. In fact, as suggested above, Shchapova's own data on the glass from the Uspenskii Sobor can be interpreted as an excellent example of how Rus' and Byzantine masters worked together. Thus, there is no compelling reason to believe that Rus' and Byzantine glassmakers worked separately and that each used a distinct ethnic recipe. Rather, Byzantine masters taught their Rus' students and colleagues how to employ a variety of recipes. The two groups, working "side by side" in Lazarev's phrase,[60] adorned the early Rus' masonry churches and, as we shall see, also began to produce various goods such as glazed pottery and glass beads.

From the first, the visiting Byzantine glassmakers taught their Rus' helpers and apprentices in Kiev how to make glass. Therefore, it is not surprising that many elements of the ancient Mediterranean glassmaking tradition appeared in Rus', both in terms of the raw materials used and the techniques employed. The Rus' quite naturally copied from their Byzantine teachers. But the fact that Rus' masters sometimes used the same materials and methods as the Greek glassmakers does not prove that Greeks in Kiev made glass for over two centuries. It merely shows that the Byzantine legacy was never completely lost in Rus'. For over two centuries, some Rus' glassmakers, as well as occasional Greek visitors, kept the Byzantine tradition alive and continued to experiment with it.

Furthermore, it also seems clear that the Byzantine glassmakers who came to Kiev sporadically were far from being rigid traditionalists. Like the Rus', they experimented with a variety of recipes and did not hesitate to

borrow from their Rus' colleagues. Thus, the chemical composition of glass from pre-Mongol Rus' is a very imperfect indicator of the ethnicity of its makers.

In sum, a critical analysis reveals serious problems with Shchapova's ethnic taxonomy of glass from pre-Mongol Rus'. Rather than the separate and distinct schools portrayed by Shchapova, it would appear that:

1) the Rus' learned the art of glassmaking from Byzantium shortly after Grand Prince Vladimir's conversion ca. 988;

2) Byzantine masters were invited to Rus' on several occasions after 988 to help with the mosaics and glazed tiles desired in the early Rus' cathedrals;

3) while Greek masters thus visited Rus' to help decorate churches, the evidence suggests that few settled there permanently;

4) Rus' glassmakers, along with a few visiting or resident Greek masters, employed a great variety of recipes in producing glass;

5) the recipes used by the Rus' glassmakers included the traditional Mediterranean soda-lime recipe and its variants as well as various lead silicate recipes;

6) the most widespread Rus' recipe, KPbSi, should be considered a local variant of the potash glass produced in continental Europe north of the Alps starting ca. 800-ca. 1000;

7) the low level of technology and scientific knowledge, as well as the impurities in the raw materials, suggest that we should be very cautious in making sweeping generalizations about the ethnicity of glassmakers based on the composition of medieval Rus' glass; and, finally,

8) rather than competing, it is far more likely that Rus' and Byzantine masters cooperated and, as several Soviet specialists assert, even worked together in the same workshops.

The Origin of the Lead Glasses Used in Pre-Mongol Rus'

The second major question arising from Shchapova's analysis of the Kievan glass industry concerns the origins of the lead silicate glasses, primarily PbSi and KPbSi, made in early Rus'. As we have already seen, lead silicate recipes were *not* characteristic of either Byzantium or Western Europe. Because of this, Shchapova and others have argued that lead silicate glasses were distinctly Rus'--i.e., the Rus' did not borrow the recipes from Byzantine glassmakers. At the same time, Shchapova has also maintained that Rus' lead silicate glass, in its simpler PbSi variant, was already being produced ca. 1000, almost immediately after glassmaking was introduced into Rus' by Greek masters. It is hard to believe that the novice Rus' glassmakers of ca. 1000, only recently initiated into the secrets of glassmaking, quickly discovered all by themselves how to produce glass using a completely different recipe than that employed by Greek glassmakers. There seems little doubt that the Rus' borrowed the recipe for PbSi glass from abroad. Once this recipe was adopted in Rus', the addition of potash to the original PbSi glass can easily be explained by the content of the plant and/or tree ash found in continental areas like the middle Dnepr and the fact that potassium definitely improves the quality of leaded glass.

From whom, then, did the Rus' learn how to make a lead silicate glass and how did this borrowing lead to the establishment of a glass industry in Rus'? Surprisingly, the appearance of lead silicate glass in Rus' has not received

much attention from Soviet scholars. They seem content mainly to note the presence of lead recipes amongst the earliest Rus' glass, while devoting most of their attention to the development of lead glass within Rus' after about 1000. The unexpected appearance of lead glass in early Rus' has been noted by non-Soviet scholars but they are apparently waiting for some explanation from their Soviet colleagues.[61] Thus, we still lack a detailed examination of how the Rus' first came to use a lead silicate recipe for most of their glass.

This brief study does not pretend to be the comprehensive analysis of the origins of Rus' leaded glass which is so clearly needed. Furthermore, this author is not a specialist in medieval glass who is conversant with all the many nuances of the problem. Nevertheless, I shall attempt to put forward a working hypothesis which hopefully will stimulate the specialists to address this issue.

If the Rus' learned of lead glass from some country other than Byzantium, which country could this have been? The Orthodox Bulgarians of the Balkans apparently have to be ruled out since they used the non-leaded ancient glass recipe.[62] Furthermore, it seems that we must also exclude the medieval Christian Caucasus, where the glass had a soda-lime-silica or soda-potash-lime-silica composition.[63] Finally, medieval Central Asia should be ruled out since it also produced soda-lime-silica and potash-lime-silica glasses.[64] In other words, lead glasses were apparently not made in any of the major adjacent glassmaking centers from which the Rus' might have borrowed a recipe.

An examination of Bezborodov's data on the various types of medieval lead silicate glass shows that lead silicate glass has been found in Rus', Poland, Japan, and Indonesia.[65] A more recent study reports finds of lead silicate glass from several spots along the southern Baltic coast now in East or West

Germany, as well as from Sweden and the Northern Caucasus.[66] We can safely exclude Japan and Indonesia as potential sources for the Rus' leaded glass. Similarly, the few isolated finds of leaded glass from North Germany, Sweden, and the Northern Caucasus do not suggest any significant local production that would attract the Rus'. Thus, based on current data, we must turn to Poland when seeking the potential source of the leaded glass found in Rus'.

The question now facing us is whether the appearance of lead silicate glass in both Rus' and Poland during the early Middle Ages was a coincidence or whether it resulted from some borrowing between the two lands. The production of leaded glass in Poland dates from the first half or middle of the tenth century--that is, at least a half century before such glass was made in Rus'.[67] Furthermore, the remains of a workshop for the transformation of glass dating from the mid-ninth to the late ninth/early tenth century have been excavated at Szczecin along the Polish coast.[68] Evidence of glassmaking dating from the first half of the tenth century has also been uncovered at Opole in Poland.[69] Thus, by the year 1000, when the Rus' began to make glass, a tradition of glassmaking existed in Poland, among whose products was lead silicate glass.

While a *prima facie* case can be constructed for the Rus' borrowing of lead silicate glass from neighboring Poland, such a case also faces several difficulties. First of all, as an analysis of the materials from Szczecin has shown, different types of glass were present at early medieval Polish sites. At Szczecin, for instance, glass made from the following recipes was found: K_2O-Na_2O-CaO-MgO-Al_2O_3-SiO_2 (mid-eighth to first quarter of the ninth century complex and last quarter of the ninth to first half of the tenth century complex); K_2O-Na_2O-CaO-MgO-SiO_2 (mid-ninth to late ninth-early tenth century

complex); K_2O-CaO-(Al_2O_3?)-SiO_2 (mid-ninth to late ninth/early tenth century complex); CaO-K_2O-MgO-SiO_2 (first half of the tenth century complex); and PbO-Na_2O-CaO-SiO_2 (workshop of the mid to late ninth/early tenth century).[70] It should also be noted that the glass workshop at Wolin produced a lead silicate glass of the type PbO-Na_2O-CaO-SiO_2.[71] The early glass found in Poland, while diverse, appears to diverge from most early Rus' glass in terms of composition. The early Polish potash glasses, for example, contain lime (CaO) and even soda (Na_2O). The presence of such elements would seem to link this glass more with West European potash glass than with the Rus' potash glass. Similarly, the Polish lead silicate glass contains soda and lime, which do not constitute significant elements in most early Rus' leaded glass. We should reiterate, at this point, Frank's words of caution about drawing sweeping conclusions from glass analysis.[72] There is clearly a coincidence in the composition of some early Polish and Rus' glasses, a coincidence which leaves open the possibility for borrowing. But if the Rus' lead silicate glass originally derived from Poland, then the Rus' appear to have greatly altered the Polish recipe for much of their production.

The Polish origins of the Rus' silicate glass are also called into question by the nature of the early Polish glass workshops. Dekowna argues, for example, that the workshop at Wolin did not make raw glass itself. It purchased raw glass from elsewhere and then transformed it into finished goods.[73] Similarly, she believes that the workshop at Szczecin also made finished goods from raw glass produced elsewhere.[74] In fact, Dekowna even speculated that the two beads of PbNaCsSi glass from Szczecin which were analyzed may have been imported, either from the Orient or from some unknown European center.[75] Thus, the objects of lead silicate glass produced in Poland

prior to 1000 may well have been fashioned from raw glass made elsewhere. And Dekowna admits in a recent study that specialists cannot yet say where this early medieval lead silicate glass was first produced or how it reached Northern Europe.[76] Until these problems are resolved, it would be premature to seek the origins of Rus' leaded glass in Poland.

Finally, it is pertinent to emphasize that we do not have any written sources indicating that the Rus' learned how to make leaded glass from Polish or Baltic Slavic masters. Unquestionably, there is a lack of sources for many, if not most, events which took place in early medieval Eastern Europe and it would be unreasonable to demand written sources as verification for all developments suggested by non-written sources. But, when several contemporary written sources clearly point to Byzantium as the inspiration behind Rus' glassmaking, it would be helpful to have at least one comparable source if another place of origin, such as Poland, were to be proposed.

As the above discussion indicates, there are several difficulties in viewing Poland as the source of Rus' leaded glass. At the same time, we possess strong positive evidence linking the origins of Rus' glassmaking with Byzantium, and the historical circumstances for this linkage are quite compelling. Following the conversion of Rus', Byzantine masters were invited to Rus' to construct Byzantine-inspired churches as well as to adorn them in the Byzantine fashion. Thus, while not ruling out Poland completely, there are very good reasons to ask whether leaded glass might have come to Rus' from Byzantium, despite Shchapova's arguments against the Greek origin of Rus' leaded glass.

It seems to me that part of our problem in seeking the origin of Rus' leaded glass stems from the assumption that early Rus' masters must have

learned their craft from Byzantine glassmakers. In fact, it appears that the earliest Byzantines who were invited to adorn Rus' cathedrals were not glassmakers in the narrow sense of the word--i.e., makers of glass vessels and ornaments--but craftsmen asked to produce glazed tiles and mosaics. Now Biek and Bayley have pointed to "the strange lack of contact between workers with glazes and workers in glass."[77] They go on to suggest that there may have been "some sort of demarcation between potters (who would glaze) and metalworkers who would use glasses in enamel work."[78] These comments indicate that, in searching for the sources of Rus' leaded glass, we might do well to consider the status of glazes and especially lead glazes in Byzantium prior to ca. 1000.

Lead silicate glazes were widely used on pottery in the Roman world all the way from Asia Minor to Britain.[79] There has been much controversy, however, about the fate of glazed pottery in the Mediterranean world after the fall of Rome. Some scholars argue for a continuity of lead glazing in Italy while other specialists believe that glazed pottery disappeared for several centuries in the Western Mediterranean and perhaps even in Byzantium.[80] Leaving aside the question of whether lead glazing continued in the Western Mediterranean or was reintroduced from Byzantium and/or Islam, recent research leaves no doubt that lead glazed pottery was produced in Constantinople from the seventh/eighth century onward.[81] In fact, by the late eighth-ninth century, the use of lead glaze on pottery was being diffused from Byzantium to Italy.[82] Thus, there can be no doubt that in the tenth century a number of Byzantine craftsmen were very experienced in the art of lead glazing.

As we have seen, various Rus' rulers of the late tenth and eleventh centuries asked Byzantine masters to come to Rus' to adorn their new cathe-

drals with glazed tiles and mosaics. Glazed decorative tiles were used, for instance, in the two earliest masonry cathedrals of Kiev--the Church of the Tithe (991-996) and the Church of St. Sophia (1037-1046). An analysis of the glaze used in the tiles from both churches shows that it was made from a PbSi recipe with relatively high levels of coloring agents such as tin and iron.[83] Since the glazed tiles from the Church of the Tithe and St. Sophia are "absolutely the same," T. I. Makarova, the leading Soviet specialist on medieval Rus' glazed ceramics, has argued that a workshop making glazed pottery must have functioned uninterruptedly in Kiev between the 990s and 1040s.[84]

Makarova has also suggested that the workshops making glazed tiles for the earliest Rus' churches began to produce white clay vessels covered with green glaze as a secondary activity.[85] In other words, the masters of lead glazing began to make other types of glazed pottery besides tiles in order to support themselves and meet the local demand for fine Byzantine-type wares. An analysis of this earliest Rus' glazed pottery has shown that it belongs to a PbCaSi glass with a comparatively high aluminum content--i.e., a type of glass which was widely used in Byzantium for glazing pottery.[86] Finally, Makarova maintains that both Rus' and Greek masters worked in these glazing workshops and that they made items that were Greek in recipe but Rus' in style.[87] Or, in another formulation, she says that these early glazing workshops in Kiev used Rus' raw materials but Byzantine technique.[88] Thus, the glazing of tiles and then other ceramics constitutes one example of how a lead silicate Byzantine glass, in the form of glaze, was introduced into Rus' and quickly adopted by Rus' masters.

In addition to glazed tiles, Byzantine masters were invited to adorn the

earliest cathedrals of Kiev with mosaics. In fact, it is widely accepted that Greek mosaicists worked on the Church of the Tithe in the 990s, the Church of St. Sophia in the 1040s, the Uspenskii Sobor or Church of the Dormition in the 1080s, and the Church of the Archangel Michael ca. 1108.[89] Thus, mosaics constitute another means by which a lead silicate recipe might have been introduced into Rus' from Byzantium.

Fortunately, the mosaics from several of the early Rus' churches have been subjected to scientific analysis.[90] But, for our purposes, the results are complex and not as clear-cut as in the case of lead silicate glazes. According to Bezborodov's data, mosaics from the eleventh century churches of Kiev were made from the following recipes: NaCaSi (6 samples); NaCaMgSi (1); NaCaAlSi (1); PbSi (4); KPbSi (1); NaPbSi (3); and KNaPbSi (1).[91] While the seventeen mosaic cubes, or tesserae, included in Bezborodov's tables are too few to serve as the basis for any definitive conclusions, they do suggest that the mosaics of the Kievan cathedrals were made from a variety of recipes.

More recent analyses have attempted to refine and expand Bezborodov's data. Levitskaia, for example, requested a chemical analysis of ten tesserae and a spectral analysis of thirty-four tesserae, all from St. Sophia's in Kiev. The chemical analysis showed two basic types of glass: NaCaSi (6) and PbSi (4). The spectral analysis indicated that twenty tesserae belonged to the first type, while seven tesserae were classified as PbSi glass.[92] Thus, scientific analysis demonstrated that the mosaics from St. Sophia were made from two basic types of glass.

As noted above, glass or smalt made of lead has several advantages. Leaded glass, for example, is easier to melt than lime glass and is also very propitious for coloring. Given these circumstances, Levitskaia asked why Rus'

mosaicists, who knew about the various glass recipes and understood that higher temperatures were needed for a lime-silica glass, still used the ancient recipe. In her discussion, she did not mention the force of tradition, which was perhaps a factor for at least some Byzantine glassmakers. But Levitskaia did note that lead was an import and thus was probably more expensive than soda-lime glass with its high silica/sand content. Furthermore, lead required preliminary treatment before being used in glass making. However, Levitskaia concluded that the chief reason mosaicists employed the NaCaSi glass recipe was "the optical properties of sodium-lime smalt, which were necessary for the achievement of decorative effects."[93] Of the nineteen color groups studied, ten were composed largely of alkaline metals (sodium), calcium, and silica.[94] Mosaics of sodium-lime glass had a moderate richness of color tone, several gradations of brightness, and a good texture on the surface of the tesserae.[95] In short, smalt made from a sodium-lime glass was most appropriate for certain parts of the mosaic composition.[96]

At the same time, lead was found in seven of the nineteen color groups. These color groups included: green with a shade of pure cobalt green; yellow-green; green with a brown shade; orange-yellow; dark red with a brown shade; yellow with a slightly green shade; and black and dark grey. Most importantly, Levitskaia comments that it was not possible "to obtain these colors using a lime-sodium glass" since, at the high temperatures needed for NaCaSi glass, they decomposed.[97] Furthermore, in contrast to alkaline-silica smalt, tesserae of a lead-silicate glass had a flat surface, a brightness, a richness of color tone, and compactness. Such tesserae were most appropriate for various aspects of a mosaic design.[98]

Levitskaia's analysis of the mosaics from St. Sophia in Kiev puts the

whole question of the use of various glass recipes in Rus' into an intelligible framework. The Greek mosaicists invited to Rus', as well as the native mosaicists they trained, wished to utilize tesserae with a variety of colors, degrees of brightness, and different surface textures. For certain colors like black, yellow, green and greenish hues, or copper in a lead recipe, produced the best results.[99] In sum, "the composition of the [mosaic] cubes was dictated, in general, by the artistic plan of the mosaicist."[100] With this context in mind, it now becomes clear that various glass recipes were used by the early mosaicists in Rus' cathedrals because different recipes produced tesserae with different properties. And in the execution of a large mosaic or series of mosaics, tesserae with a great variety of properties were necessary to obtain the artistic effect desired by the mosaicists.

Levitskaia's analysis of the mosaics from the Church of the Archangel Michael in Kiev (ca. 1108) reaffirms the basic conclusion drawn from her study of the St. Sophia mosaics. The chemical composition of the glass used for the tesserae depended upon the artistic design of the mosaicists. The yellow and green mosaics were made of a PbSi smalt. In fact, the colored tesserae in the Church of the Archangel Michael were mainly done from a lead-silica glass, apparently because green and yellow were two of the primary mosaic colors in the mosaic ensemble. Of the sixteen mosaic color groups, six consisted of various shades of green, while there were four groups with different orange hues.[101] In sum, aesthetic considerations seemed to dictate which type of glass recipe was to be employed and in what quantity.

We are now in a position to offer a realistic working hypothesis on how the recipe for making leaded glass was transferred from Byzantium to Rus'. When the early Rus' princes invited Greek masters to adorn their new masonry

cathedrals, the artists who responded were specialists in the glazing of tiles, as well as mosaicists. These masters quickly established workshops in Kiev located near the cathedrals which they were to decorate. It is not clear whether they shared the same workshop, where all the needed glasses were made, or whether they set up separate glazing and smalt workshops. In any event, these masters in what we may call the decorative glass arts soon branched out beyond glazing and mosaics. As we have seen, the masters of lead glazes soon began to produce pottery covered with a green lead glaze. Similarly, as Shchapova noted, mosaicists began to use the leftover or surplus glass originally intended for smalt to produce glass beads.[102] Indeed, as we have already seen, the masters in the decorative glass arts had to branch out into other spheres of activity. Once they had finished with a particular church, their work was done. While Byzantine masters could return home in search of new church commissions, the local Rus' masters, as well as the few Greeks who remained, had to develop new products to support themselves. Thus, the development of the glazed ceramic and glass good industries was the result, in part, of the need by Greek and Rus' masters to find continued employment. But we must also remember that the glazed pottery and, especially, the glass industry arose to meet the growing demand in Kiev for Byzantine luxury goods. These industries could not have grown and flourished if it had not been for the desire within Rus' for glazed pottery and glass goods. Thus, the decoration of churches with glazed tiles and mosaics inevitably led to the production of glazed ceramics and various glass goods.

In decorating the Rus' cathedrals, the mosaicists employed a variety of recipes in order to obtain tesserae with different hues and degrees of opacity, and several surface textures. Among these recipes was that for PbSi

smalt and it was this recipe in particular which initially found favor among the new producers of glass beads. By the second quarter of the eleventh century, potash was added to this glass recipe for reasons discussed above. I shall leave it to specialists in glass to explain why the PbSi recipe for smalt, in particular, was chosen for the initial manufacture of glass beads. While the choice may well have been accidental or the result of trial and error, we should also consider the possibility that there were some logical technical reasons which pointed the first makers of glass beads in Rus' towards PbSi glass. These logical technical considerations might also explain why some of the PbSi glass consisted of about seventy percent lead while other PbSi glass only contained about twenty-five percent lead. In any event, the development of a leaded glass industry in Rus' was the outgrowth of the lead glazes and lead smalt used to decorate the earliest Rus' masonry cathedrals. The recipes used both in decorating churches and making products were chosen for technical, economic, and aesthetic reasons, not because of some overriding ethnic tradition.

In conclusion, the adoption of PbSi and KPbSi glass recipes in Rus' can be seen as a logical development which took place as Byzantine and Rus' masters adapted the recipes used for glazed tiles and mosaics to the needs of glazed ceramics and glass goods. The adoption of lead silicate glass recipes was thus an integral part of the development of a glass industry in Rus' based on Byzantine origins.

In Lieu of a Conclusion

This paper has attempted to reexamine several current ideas concerning the early Rus' glass industry. It has been argued here that this industry was

created by Greeks and Rus' who worked together using various recipes and that the leaded glasses so characteristic of early Rus' production came from Byzantium via glazes and mosaics. As noted in the introduction, this paper forms part of a larger research project. A companion piece seeks to explain why glassmaking technology was imported by Rus' from Byzantium in the aftermath of Vladimir's conversion and not earlier or later.[103] Originally, I had planned to conclude my research on how Vladimir's conversion served as a catalyst for Kievan industrial development with these two papers. However, Professor George Majeska, who commented on this research when it was presented at the Kennan Institute Seminar Series, suggested that I broaden my horizons to consider other conversion-inspired industries such as church construction, icon painting, and book copying. Acting on this good idea, I will now look beyond glass production and examine the variety of new industries that arose in Rus' as the result of its conversion. Finally, in the course of my research, I discovered that a Bulgarian glass industry appeared soon after Bulgaria's conversion to Orthodoxy.[104] As a result, I would now like to explore whether there was any general pattern or process by which the acceptance of Christianity from Byzantium led to technology transfer and industrial development among the medieval Slavic peoples. Clearly, we have only begun to scratch the surface in our understanding of how conversion fostered industrial growth in Eastern Europe.

Endnotes

1. Novoe v arkheologii Kieva (Kiev: 1981), 312.
2. See George Vernadsky, *Kievan Russia* (New Haven: 1948), 116, where it is categorically stated that "there is no evidence that glass was produced in Kievan Russia."
3. *Novoe v arkheologii*, 312.
4. Ibid, 318.
5. Among the key works are: M. A. Bezborodov, *Steklodelie v drevnei Rusi* (Minsk: 1956); Id., *Khimiia i tekhnologiia drevnikh i srednevekovykh stekol* (Minsk: 1969), German tr. *Chemie und Technologie der antiken und mittelalterlichen Gläser* (Mainz: 1975); Iu. L. Shchapova, "Drevnerusskie stekliannye izdeliia kak istochnik dlia istorii Russko-Vizantiiskikh otnoshenii v. XI-XII vv.," *Vizantiiskii Vremennik* 19 (1961), 60-75; Id., "Stekliannye izdeliia drevnego Novgoroda," in *Novye metody v arkheologii* [Materialy i issledovaniia po arkheologii SSSR, No. 117] (Moscow: 1963), 104-163; Id., *Steklo Kievskoi Rusi* (Moscow: 1972); Id., "Novye materialy k istorii mozaik Uspenskogo Sobora v Kieve," *Sovetskaia Arkheologiia*, 1975, No. 4, 209-222; Id., *Ocherki istorii drevnego steklodeliia (po materialam doliny Nila, Blizhnego Vostoka i Evropy* (Moscow: 1983). There are also several useful articles in western languages by Soviet specialists in medieval Rus' glass, e.g. M. A. Bezborodov, "A Chemical and Technological Study of Ancient Russian Glasses...," *Journal of the Society of Glass Technology*, 41 (1957), 168-184; B. A. Shelkovnikov, "Russian Glass from the 11th to the 17th Century," *Journal of Glass Studies* 8 (1966), 95-115; Julie Scapova, "A propos de l'histoire du verre de la Russie ancienne," *Annales du 5e Congrès de l'Association Internationale pour l'Histoire du Verre* (Liège: 1972), 89-97; Julia Léonidovna Shchapova, "Apparition de la verrerie chez les Slaves Orientaux," *Rapports du IIIe Congrès International d'Archeologie Slave, II* (Bratislava: 1980), 385-391.
6. The data shown here is drawn from Shchapova's works cited in note 5 and T. N. Nikol'skaia, *Zemlia Viatichei: K istorii naseleniia basseina verkhnei i srednei Oki IX-XIII vv.* (Moscow: 1981), 237-238, for Serensk.
7. *The Russian Primary Chronicle: Laurentian Text*, tr. and ed. S. H. Cross and O. P. Sherbowitz-Wetzor (Cambridge, MA: 1953), s.a. 989, 119.
8. Shchapova, *Ocherki*, 183.
9. Shchapova, "Novye materialy," 211.
10. The best account of the Kievan Greek glassmakers can be found in Shchapova, "Drevnerusskie stekliannye izdeliia."
11. This is a composite account of early Rus' glassmaking drawn from Shchapova's studies cited in note 5.
12. Shchapova, *Steklo*, Table 30, 166.
13. For those like myself who are novices in the area of medieval glassmaking, I strongly recommend Susan Frank, *Glass and Archaeology* (London, New York: 1982), which also contains a very useful bibliography. Interested readers will also profit from the important series of articles by W. E. S. Turner under the title of "Studies in Ancient

Glasses and Glassmaking Processes" in the *Journal of the Society of Glass Technology:* "Part III. The Chronology of the Glassmaking Constituents," 40 (1956), 39T 52T; "Part IV. The Chemical Composition of Ancient Glasses" 40 (1956), 162T 186T; and, "Part V. Raw Materials and Melting Processes." 4 (1956), 277T, 300T.

14. This recipe, in its more precise scientific form, was mNa_2O-nCaO-pSiO_2.
15. Shchapova, "Drevnerusskie stekliannye izdeliia," 60-71.
16. Frank, *Glass and Archeology*. 75, 79; Turner, "Raw Materials," 277T, 288T. It is also true that coastal ash can contain potash while continental ash can contain soda (Turner, "Raw Materials," 285T, 296T).
17. Shchapova, "Stekliannye izdeliia Novgoroda," 114.
18. Shchapova, "Novye materialy," 215, speaks of the Greek glassmakers in Kiev making use of imported raw materials.
19. Bezborodov, *Chemie und Technologie*, 310-315.
20. Ibid, 316-321.
21. Leo Biek and Justine Bayley, "Glass and other Vitreous Materials," *World Archaeologus* 11 (1979-1980), 3, 10-14, 16.
22. Ibid, 16; Frank, *Glass and Archaeology* 7, 82, 84.
23. Biek and Bayley, "Glass," 17-19; Turner, "Chemical Composition" 175T; R.J. Charleston, "Lead in Glass," *Archaeometry*, 3 (1960), 1-4. Frank, *Glass and Archaeology*, 83, and Turner, "The Chronology," 47T, discuss medieval Western European glass recipes involving the use of lead.
24. Biek and Bayley, "Glass," 17.
25. Ibid, 17. Also see Frank, *Glass and Archaeology* 84, for the very positive qualities of KPbSi glass.
26. Bezborodov, *Chemie und Technologie*, 316-321; Id., "A Chemical and Technological Study," 168-184.
27. Frank, *Glass and Archeology* 21-22, 24-25, 71, 76-77; Biek and Bayley, 21 (1980), 1, "Glass," 4; R. G. Newton, "Recent Views on Ancient Glass," *Glass Technology* 21 (1980), p. 178.
28. Bezborodov, *Chemie und Technologie*, 270-279.
29. Frank, *Glass and Archaeology*, 74-77. There is a good twelfth century account of continental European glassmaking by the German monk Theophilus, *De Diversi Artibus/The Various Arts*, Book II, "The Art of the Worker in Glass," tr. C. R. Dadwell (London: 1961) and tr. John G. Hawthorne and Cyril S. Smith (Chicago: 1963).
30. Frank, *Glass and Archeology*, 76; Newton, "Recent views," 178-179.
31. It should be noted here that medieval potash glass is far less durable and far more susceptible to corrosion than the Roman soda and lime glass. Lime, in particular, makes glass less liable to corrosion by moisture. This explains why medieval European glass is scarce in comparison with Roman glass. The recipes used to make glass have thus determined, in large part, how much glass has survived. See Frank, *Glass and Archaeology* 13, 24, 75, 77, 90.
32. Turner, "The Chronology," 39T, 45T-46T; Turner, "Raw Materials," 282T-283T, 297T; Frank, *Glass and Archaeology*, 72, 75; Biek and Bayley, "Glass,"
33. Shchapova, "Novye materialy," 211.
34. Frank, *Glass and Archeology*, 71; Turner, "The Chronology," 39T, 44T.
35. Turner, "The Chronology," 40T, 46T-47T.
36. Frank, *Glass and Archaeology*, 122.

37. Shchapova, "Novye materialy," 217, 219.
38. Ibid, 219.
39. Ibid, 213-214.
40. Turner, "The Chemical Composition," 169T.
41. Ibid, 178T.
42. Turner, "The Chronology," 48T-49T. Also see Biek and Bayley, "Glass," 6-7.
43. Shchapova, "Novye materialy," 218.
44. Ibid, 218-219.
45. Ibid.
46. Ibid.
47. Ibid, 211.
48. Bezborodov, *Chemie und Technologie*, 272-275.
49. Fourteenth century Czech KCaMgSi glass had no phosphorus either; see Bezborodov, *Chemie und Technologie*, 272.
50. Shchapova, "Novye materialy" 219.
51. Ibid, 220-221.
52. See note 7 for the Church of the Tithe constructed in the 990s. The written sources on the Greek masters invited to direct the construction of the Uspenskii Sobor ca. 1080 are mentioned by Shchapova, "Novye materialy," p. 209, n. 4-5, and p. 221. There seems little doubt that Greek masters were also given the chief role in the decoration of the Cathedral of St. Sophia in Kiev, which was built during the 1040s; see Shchapova, "Novye materialy," 221.
53. Viktor Lazarev, *Old Russian Murals and Mosaics* (London: 1966), 13.
54. Ibid, 15, 18.
55. D. Abramovich, ed., *Kievo-Pecherskii Paterik* (Kiev: 1930), 9-11, cited in Lazarev, *Old Russian Murals*, 72.
56. Lazarev, *Old Russian Murals*, 72.
57. Ibid, 74; V.I. Levitskaia, "O palitre Mikhailovskikh mozaik," in V. N. Lazarev, *Mikhailovskie mozaiki* (Moscow: 1966), 126, concluded that there was nothing to connect the mosaics of St. Sophia (1040s) with those of the Church of the Archangel Michael (ca. 1108).
58. Shchapova, "Novye materialy," 210.
59. Lazarev, *Old Russian Murals*, 14.
60. Ibid, 18. Also see Lazarev, *Mikhailovskie mozaiki*, 90, 99-100, for the close cooperation of Byzantine and Rus' mosaicists. T. I. Makarova, *Peregorodchatye emali Drevnei Rusi* (Moscow: 1975), 95, also comments on the Graeco-Rus' composition of the earliest Rus' mosaic workshops.
61. Charleston, "Lead in Glass," p. 1, notes, for instance, "the surprisingly high ratio of lead in many glasses of Russian provenance" while Biek and Bayley, "Glass," p. 18, mention the "extraordinary group of Russian medieval glass...."
62. Shchapova, "Novye materialy," 219; Bezborodov, *Chemie und Technologie*, 154, 238-243.
63. Bezborodov, *Chemie und Technologie*, 154-155, 238-243, 248-253 260-263, 266-269, 292-293, 306-309.
64. Ibid, 154-155, 238-241, 248-253, 266-269, 272-273, 278-279, 282-301, 306-309.
65. Ibid, 155, 310-327.
66. Maria Dekowna, "Remarques sur la chronologie de l'introduction dans la verrerie europeenne medievale de la technologie potassique et de celle

au plomb non-alcaline," *Annales du 8e Congrès International d'Étude Historique du Verre* (Liege: 1981), 157-160.

67. Ibid, 157; Bezborodov, *Chemie und Technologie*, 310-311, 322-323, notes lead silicate glass of the ninth century from Wolin in Poland.
68. Dekowna, "Remarques," 147; Id., "Problème de l'existence d'un atelier verier à Szczecin au haut moyen age," *Annales du 6e Congrès de l'Association Internationale pour l'Histoire du Verre* (Liege: 1974), 143-158.
69. Maria Dekowna, "Étude sur les origines de la verrerie en Pologne," *Annales du 3e Congrès International d'Étude Historique du Verre* (Liège: n.d.--post-1964), 124, where the workshop is dated to the second half of the tenth century. However, in a more recent work ("Problème de l'existence," 157), Dekowna dates the glass workshop at Wolin to the first half of the tenth century.
70. Dekowna, "Remarques" Table I, p. 149; Id., "Problème de l'existence," 147-148.
71. Dekowna, "Problème de l'existence;" 157.
72. See note 36.
73. Dekowna, "Problème de l'existence," 157.
74. Ibid.
75. Ibid.
76. Dekowna, "Remarques," 160.
77. Biek and Bayley, "Glass," 18.
78. Ibid, 18-19.
79. E. M. Jope, "Ceramics: Medieval," in *A History of Technology*, ed. Charles Singer et al, II (Oxford: 1957), 299; David Whitehouse, "The Medieval Glazed Pottery of Lszio," *Papers of the British School at Rome*, 35 (1967), 42-43.
80. Jope, "Ceramics," 287-288, 299; Robert B. K. Stevenson, "Medieval Lead-Glazed Pottery: Links between East and West," *Cahiers Archeologique* 7 (1954), 89-94; Whitehouse, "Medieval Glazed Pottery," 42-48; Biek and Bayley, "Glass," 19.
81. Whitehouse, "Medieval Glazed Pottery," 44-47, 56, 84.
82. Ibid, 47-48, 52-53, 56, 83-84.
83. T. I. Makarova, *Polivnaia posuda: Iz istorii keramicheskogo importa i proizvodstva Drevnei Rusi* [Arkheologiia SSR: Svod arkheologicheskikh istochnikov, E1-3] (Moscow: 1967), 36.
84. Ibid, 37.
85. T. I. Makarova, *Polivnaia keramika v Drevnei Rusi* (Moscow: 1972), 9.
86. Ibid; Id., *Polivnaia posuda*, 37-41; Iu. L. Shchapova, "Spektral'noe issledovanie polivy," in Makarova, *Polivnaia posuda* 70.
87. Makarova, *Polivnaia keramika* 9.
88. Makarova, *Polivnaia posuda* 38, 61.
89. Lazarev, *Old Russian Murals* 13-18, 31-32, 65-74. Mosaics also existed in the Church of St. Peter in Kiev (1085-1087), as well as in the episcopal residence and Church of the Archangel Michael in Pereiaslav-Khmel'nitskii (1089); see Lazarev, *Mikhailovskie mozaiki* 89.
90. In addition to the studies of Bezborodov and Shchapova mentioned earlier, see, in particular, V.I. Levitskaia's two important articles: "Materialy issledovaniia palitry mozaik Sofii Kievskoi," *Vizantiiskii Vremennik* 23 (1963), 105-157, and, "O palitre," 103-133.

91. Bezborodov, *Chemie und Technologie*, 240-243, 252-253, 260-261, 310-313, 316-317, 322-325.
92. Levitskaia, "Materialy issledovaniia," 138-145.
93. Ibid, 146.
94. Ibid.
95. Ibid.
96. Ibid, 146-147.
97. Ibid, 147.
98. Ibid.
99. Ibid, 149-151.
100. Ibid, 154.
101. Levitskaia, "O palitre," 103-133.
102. Shchapova, *Ocherki*, 184.
103. Thomas S. Noonan, "Technology Transfer Between Byzantium and Eastern Europe: A Case Study of the Glass Industry in Early Russia," in Marilyn Chiat, Kathryn Reyerson, eds., *The Medieval Mediterranean: Cross Cultural Contacts* (forthcoming).
104. Georgi Djingov, "Sur l'Origine de la Verrerie en Bulgarie au Moyen Age," in *Verre Medieval aux Balkans (V^{e}-XV^{e}s.)/Sredn'ovekovno staklo na Balkanu (V-XV vek)* (Belgrade: 1975), 112.